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CHEMICAL ENGINEERING.—*Joule-Thomson coefficients for Freon-12.*[1] RICHARD A. SCHMIDTKE. (Communicated by C. H. Page.)

The increasing demand in recent years for mechanical refrigeration because of its application to domestic refrigerators, air conditioning, and food and industrial processing has led to the development of new refrigerants. In order to make proper engineering use of these new compounds an accurate knowledge of their thermodynamic behavior is necessary. The purpose of the present investigation of the Joule-Thomson effect in Freon-12 is to add to the experimental data regarding its thermodynamic behavior.

Freon-12 (dichlorodifluoromethane) was selected for study because of its importance in engineering application. Buffington, Gilkey, and their coworkers (*1*, *2*, *3*, *4*, *5*, *6*) have prepared tables of thermodynamic properties for Freon-12 by the use of pressure-volume-temperature data together with specific heat determinations. The Joule-Thomson coefficients reported here are useful in the superheated region for verification of the previously published properties and as additional data relating to the behavior of Freon-12.

The experimental work was done in the Thermodynamics Laboratory of the Mechanical Engineering Department, Illinois Institute of Technology. The range of the data is: pressure, 15 psia to 50 psia; temperature, 100°F. to 300°F.

The Joule-Thomson experiment has been discussed in the literature many times since 1852, when Joule and Thomson (*7*) first reported their work. Although the thermodynamic theory is well known, the basis for the experimental work will be given. The definition of the Joule-Thomson coefficient, μ, is

$$\mu = (\partial t/\partial p)_h \qquad (1)$$

where the subscript h refers to partial differentiation at constant enthalpy. The particular experimental method employed, called the radial flow porous plug method, has been used by other investigators such as Budenholzer and his coworkers (*8*, *9*, *10*, *11*, *12*). It is based on the assumption that

$$\mu \approx (\Delta T/\Delta p)_h \qquad (2)$$

is sufficiently accurate provided the finite increments are kept small enough. The requirement that the enthalpy remain constant is best achieved by a steady flow process. If the First Law of Thermodynamics is applied to the steady flow process of a unit mass of substance between cross sections 1 and 2 along the flow path, the following equation results:

$$Z_1/J + V_1^2/2gJ + Q_{12} = Z_2/J + h_{12} + V_2^2/ZgJ + W_{12}/J \qquad (3)$$

Now a process which occurs with no change of elevation, no change of velocity, no external work, and no heat exchange with the surroundings would be one of constant enthalpy. The experimental apparatus was designed to meet these conditions and to permit measurement of the pressure and temperature increments as well as the pressure and temperature level of the process.

The general arrangement of the apparatus is shown schematically in Fig. 1. The compressor is a 4-cylinder reciprocating machine of about 2.7 cubic feet per minute capacity. The volume chambers served to damp out pressure fluctuations. The heating coils were each of ¼-inch diameter copper tubing about 7 feet long immersed in a

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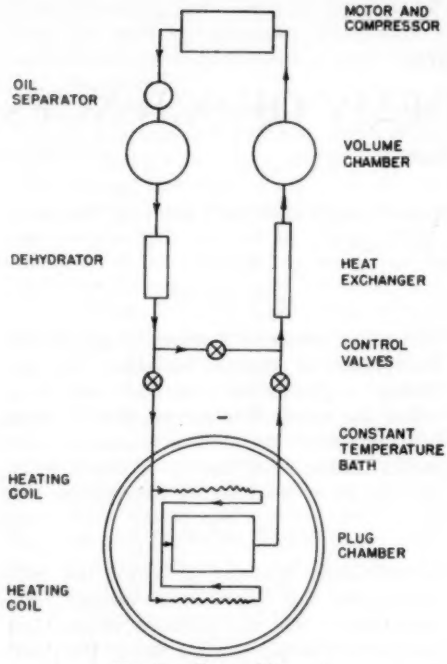

FIG. 1.—General layout

corn oil, controlled temperature bath to bring the gas to the proper temperature. The heat exchanger, a small water-cooled shell-and-tube type, is used for protecting the compressor from too high operating temperature. The valves shown are for flow control and for controlling the pressure drops in the plug chamber.

The plug chamber shown in cross section in Fig. 2 is the most important part of the apparatus as all the measurements are made there. A steel chamber with highly polished inner surfaces and aluminum foil radiation shields at E, F, and I prevent radiant heat exchange. The porous plug through which the gas flows is a modified microporous porcelain filter candle such as used for biological filtering. This thimble shaped plug is 1 inch in diameter and has an effective flow length of 3 inches. In order to satisfy the conditions stated in connection with equation 3, the chamber was placed horizontally to have constant elevation, the large flow area assures very small velocities, and no external work is done from one side of the plug to the other. The heat exchange is kept very small by the controlled bath (held to 0.1°F), the radiation shielding, and asbestos insulation within the plug chamber.

The pressure drop was measured by a mercury-in-steel manometer, which was read electrically and calibrated so that the pressure difference (measured at points C and D of plug chamber) could be determined to 0.05 psi. At the usual pressure drop of 17.9 psi used in the experiments, this amounted to an uncertainty of 0.3 percent. The copper-constantan three junction thermopile used to measure the temperature drop was calibrated at the ice point, steam point, and sodium-bromide transition point. This permitted the determination of the temperature drop to 0.01°F, which at the worst experimental case of a 1° drop amounts to 1 percent. The upstream pressure and temperature were measured to establish the state of conditions. The pressure was

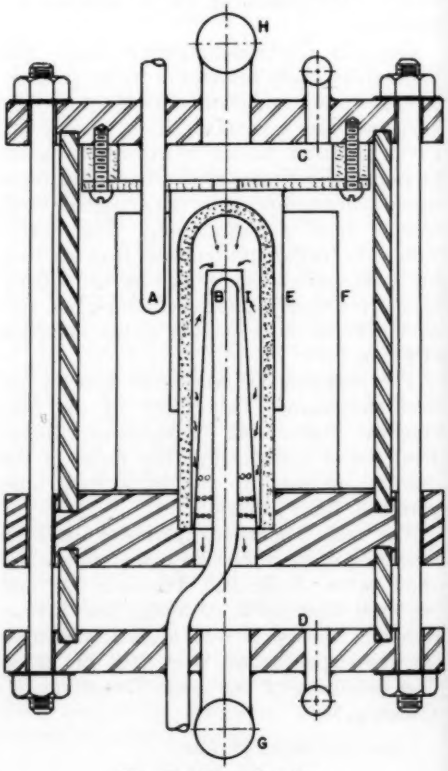

FIG. 2.—Plug chamber

TABLE 1.—JOULE-THOMSON COEFFICIENTS FOR FREON-12

TEMPERATURE (°F)	JOULE-THOMSON COEFFICIENT, μ (F/psi)			
	p 15 psia	p 25 psia	p 35 psia	p 50 psia
100	0.144	0.194	0.213	0.229
120	0.125	0.173	0.193	0.211
140	0.112	0.158	0.181	0.198
160	0.100	0.146	0.169	0.188
180	0.092	0.138	0.162	0.183
200	0.088	0.133	0.157	0.177
220	0.086	0.128	0.152	0.173
240	0.084	0.124	0.147	0.170
260	0.082	0.120	0.143	0.168
280	0.080	0.117	0.139	0.164
300	0.077	0.112	0.135	0.160

TABLE 2.—SPECIFIC VOLUME OF FREON-12 AT 15 PSIA

TEMPERATURE (°F)	SPECIFIC VOLUME (ft^3/lb) Author	SPECIFIC VOLUME (ft^3/lb) Buffington and Gilkey
100	3.266	3.266
120	3.387	3.388
140	3.507	3.510
160	3.627	3.632
180	3.745	3.755
200	3.866	3.877
220	3.985	3.998
240	4.106	4.120
260	4.225	
280	4.344	
300	4.464	

measured, depending upon its magnitude, with either a 0–60 psi or a 0–300 psi Bourdon tube gage. These gages were of excellent quality and were carefully calibrated against a dead-weight gage tester. The pressure could be determined to 0.1 psi, which at the worst conditions of 15 psia, amounts to 0.7 percent. The upstream temperature was measured with a carefully calibrated (ice, steam, sodium-bromide points) copper-constantan thermocouple. Therefore the upstream temperature was determined to 0.01°F, which at 100°F results in an uncertainty of 0.01 percent. Emf measurements were made with a Leeds and Northrop type K-2 potentiometer, Eppley Standard cell, and a Leeds and Northrop type E galvanometer.

The calculated uncertainty in the values of μ is 0.0006 F/psi, or less than 1 percent. However, owing to the slow drifts in the pressure and temperature levels reported by most other investigators of Joule-Thomson coefficients—see, for example, Roebuck (*13*, *14*)—and also the possibility of heat leakage, it is estimated that the over-all accuracy of the values of μ is about 4 percent.

The results are shown graphically in Fig. 3, which was plotted from the original data. Fig. 4 was obtained by cross-plotting from the smoothed curves of Fig. 3.

To check the values of μ found in this work, the specific volume and the compressibility factor were computed and compared with the directly measured quantities of Buffington and Gilkey (*6*). The specific volume was determined from the equation

$$v/T = v_0/T_0 + \int_{T_0}^{T} (\mu C_p/T^2)\, dT, \quad (4)$$

where v_0 and T_0 represent at an arbitrary state on the isobar of integration. The isobar was chosen at 15 psia and the reference temperature at 100°F. The isobaric heat capacity was compiled from the equation of Buffington and Fleisher (*4*) and the tables of Buffington and Gilkey (*6*) give $v_0 = 3.266$ ft^3/lb. Table 2 shows the comparison of computed and directly measured values of specific volume.

The compressibility factor is defined by the equation

$$C = pv/R_gT \quad (5)$$

TABLE 3.—COMPRESSIBILITY FACTORS FOR FREON-12 AT 15 PSIA

TEMPERATURE (°F)	COMPRESSIBILITY FACTOR Author	COMPRESSIBILITY FACTOR Buffington and Gilkey
100	0.987	0.987
120	0.988	0.989
140	0.989	0.990
160	0.990	0.991
180	0.991	0.993
200	0.991	0.994
220	0.992	0.995
240	0.992	0.996
260	0.993	
280	0.993	
300	0.994	

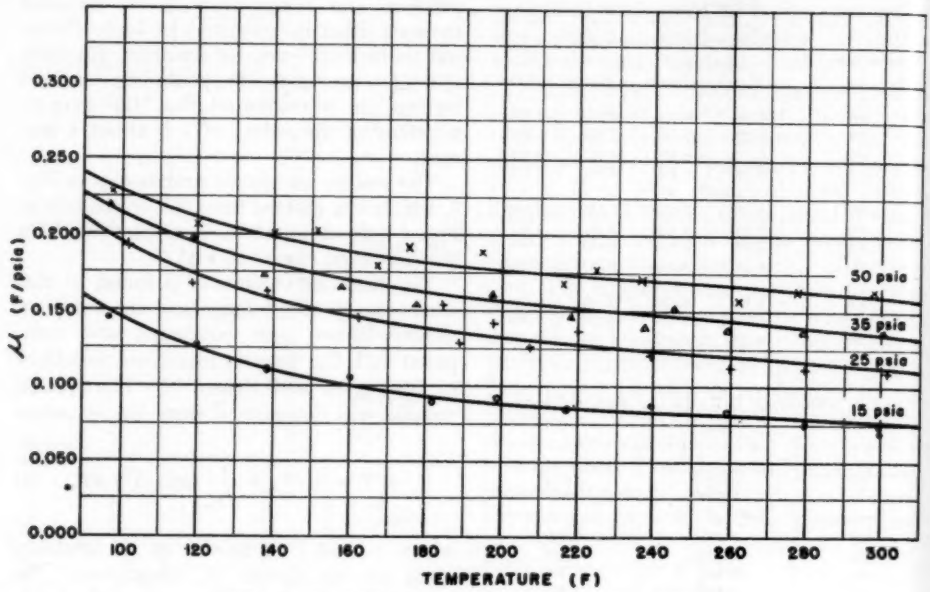

FIG. 3.—Joule-Thomson coefficient vs. temperature

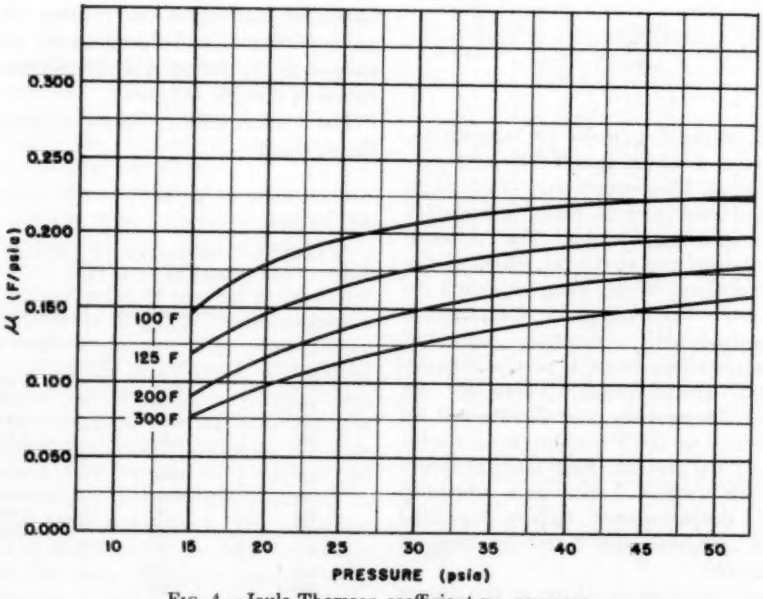

FIG. 4.—Joule-Thomson coefficient vs. pressure

It is related to the Joule-Thomson coefficient in the following:

$$C = C_0 + \int_{T_0}^{T} [p\mu C_p/R_g T^2]\, dT, \quad (6)$$

where C_0 and T_0 represent the compressibility factor and temperature at an arbitrary base state on the isobar of integration. The comparative results are given in Table 3.

ACKNOWLEDGMENT

The author wishes to express his gratitude to Dr. R. G. Owens and Dr. R. A. Budenholzer for their aid and encouragement in this work.

NOMENCLATURE

Symbol	Definition	Units
C	Compressibility factor	
C_p	Isobaric heat capacity	Btu/lb F
g	Acceleration of gravity	ft/sec²
h	Enthalpy	Btu/lb
J	Mechanical equivalent of heat	ft lb/Btu
p	Pressure	lb/ft² or psi
R_g	Gas constant	ft lb/lb R
T	Temperature	R
V	Velocity	ft/sec
v	Specific volume	ft³/lb
W	Work	ft lb/lb
Z	Elevation	ft
μ	Joule-Thomson coefficient	F ft²/lb or F/psi
Δ	Finite difference	

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The progress of science is as orderly and determinate as the movement of the planets, the solar systems, and the celestial firmaments. It is regulated by laws as exact and irresistible as those of astronomy, optics, and chemistry. S. BROWN (1843).

ENTOMOLOGY.—*Three new Neotropical flea beetles.* DORIS H. BLAKE, Arlington, Va.

Three Neotropical flea beetles of similar color pattern and representing three different genera are herewith described. All belong to obscure and little-known genera and had not been definitely placed in the U. S. National Museum collection. Two of them were with *Diabrotica pulchella* (Jacq. DuVal), a drawing of which is included (Fig. 3). Jacquelin DuVal originally described this as a *Phyllobrotica* (it is still listed as such in Blackwelder's Checklist), possibly because its color pattern resembled that of the well-known European beetle *Phyllobrotica quadrimaculata* (Linnæus).

Pseudogona subcostata, n. sp.
Fig. 4

About 6 mm in length, elongate oval, shining, very finely and obsoletely punctate, pale yellow, with the head and breast black, and on the elytra a wide basal and a preapical black band, the basal band having two elongate yellow spots near the suture. Antennae pale with joints 7 and 8 deeper brown and joints 9 to 11 paler yellow.

Head entirely dark, the interocular space one-half width of head, eyes prominent and large, occiput rounded, polished, and with a few fine punctures and two larger punctures on each side near the eye connected by a faint groove; frontal tubercles well marked, interantennal area narrowly produced into a carina extending down to labrum. Antennae not half the length of the beetle, third joint a little shorter than fourth, and fourth a little shorter than fifth, remainder subequal and gradually becoming a very little shorter. The basal six joints yellow, 7 and 8 brown, 9 to 11 paler yellow. Prothorax entirely pale, minutely punctate, about one-third wider than long, smoothly convex, without depressions, with a rounded margin, the frontal angles not wide as in *Disonycha*, or obliquely cut as in *Systena*, but small; the basal angles with a small tooth. Scutellum small and entirely dark. Elytra broader in apical half, not very convex, without depressions, shining, and with numerous fine costae, not extending the entire length and between these, rows of fine confused punctures; pale yellow with a piceous black wide basal band not extending to the middle of the elytra or to the margins, and having on each elytron an elongate pale spot near the scutellum, a piceous band also behind the middle, the apex pale. Body beneath pale except the black breast, legs pale. Anterior coxal cavities closed, posterior femora enlarged, tibiae on hind feet spurred, claws appendiculate. Length 6.4 mm; width 3 mm.

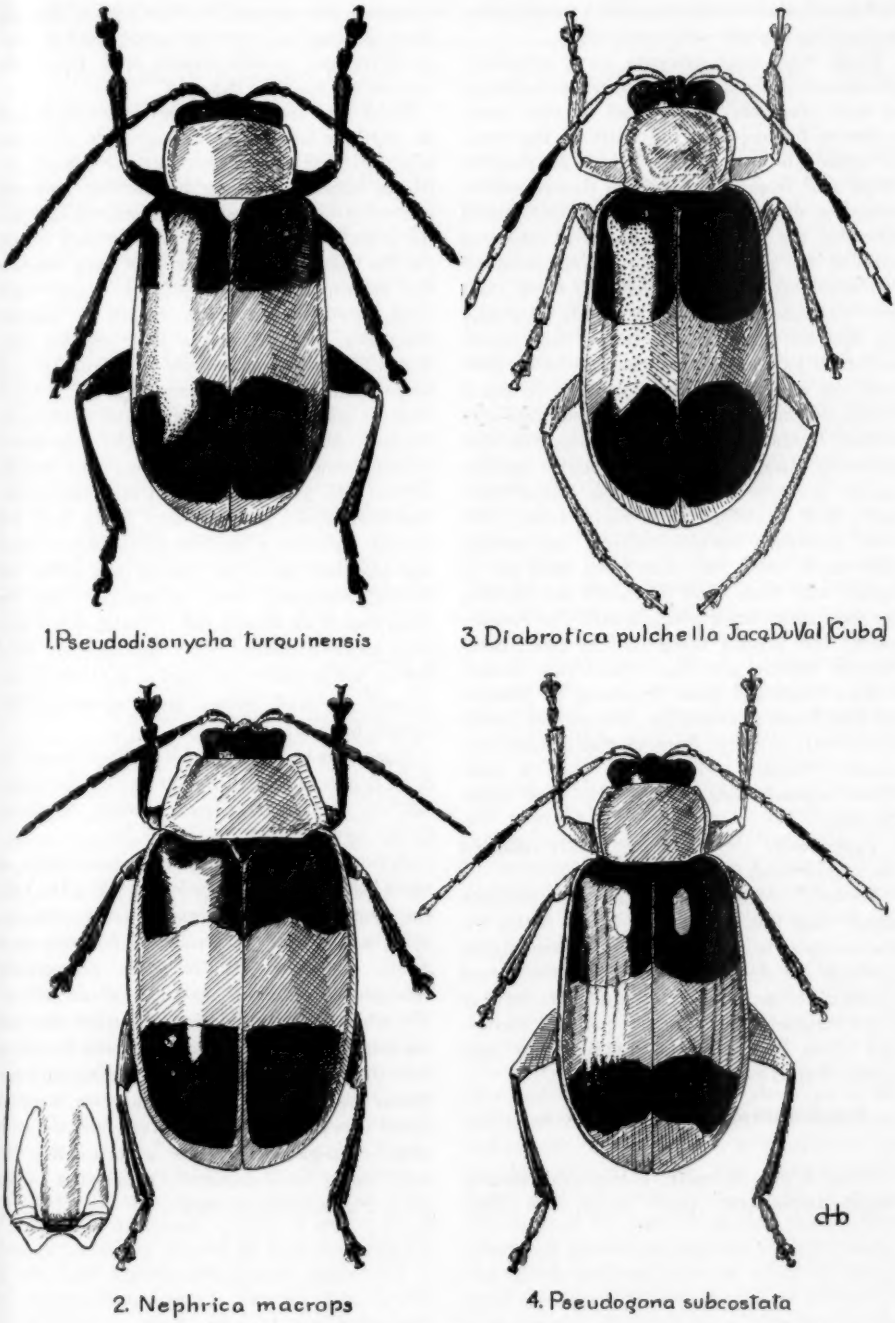
Type, female, U.S.N.M. no. 63136, collected by Schild and Burgdorf at Tucurrique, Costa Rica.

Remarks.—H. S. Barber has labeled this "Not a *Diabrotica* [which it strikingly resembles and with which it was placed] but a female Halticid, ?*Pseudogona panamensis* var. Jac." Jacoby's description of *P. panamensis*, however, differs in that there are three dark elytral fasciae instead of two, as well as different punctation. In *P. militaris* Jacoby from Panama, the basal joints of the antennae are all black and the elytra have a shallow transverse depression below the base and are opaque and not shiny. In Jacoby's description of *P. pallida* (also from Tucurrique, Costa Rica, the type locality of the present species) the color pattern is quite different, and the tibiae and tarsi are more or less black. In none of the species is there any mention of the faint elytral costation so apparent in the present species.

It is curious that although these species are all listed in the Zoological Record, Heikertinger in the Junk Catalogue omits four species of *Pseudogona*, and Blackwelder in his Checklist omits two species of this same genus. Jacoby described all six species that have comprised the genus up to the present, namely: *P. panamensis, chiriquensis, argentinensis, discoidalis, militaris,* and *pallida*. He characterized the genus as being similar to *Systena* but with differently shaped antennae and with the thorax having no groove. He stated that it differs from *Oxygona* in having a narrower, subquadrate thorax.

Nephrica macrops, n. sp.
Fig. 2

About 6 mm in length, ovate, moderately shiny, pale yellow with the upper half of head and mouthparts, the antennae, tibiae and tarsi dark, the elytra pale with a broad basal band and another below the middle not quite extending



FIGS. 1–4.—Neotropical flea beetles

to the apex, these bands dark with a metallic blue lustre. Eyes elongate and emarginate.

Head with large elongate eyes, somewhat emarginate on the inner side but not so markedly as in *N. inornata* Jacoby, and on the vertex separated by one-third the width of the head; on either side near the eye a large puncture or fovea, and from this a line of fine punctures extending down to the clearly marked frontal tubercles, the upper part of the head otherwise polished and piceous in color; carina produced and extending down the front, the lower front pale with the mouthparts brownish. Antennae not half the length of the beetle, deep brown except the two basal joints which are paler, third joint not as long as fourth, joints 4, 5, and 6 broad, the following joints becoming gradually thinner. Prothorax twice as wide as long with wide explanate margin and broadly rounded anterior angles, not very convex, shining, impunctate, pale yellow. Scutellum dark. Elytra broad, with wide explanate margin, shining, impunctate, pale yellow with a wide dark basal band and an equally wide band below the middle not reaching the apex, these bands having a dark blue metallic lustre, the margin being always pale. Body beneath entirely pale, the femora pale reddish brown, tibiae and tarsi deepening to piceous; the hind tibiae grooved, the anterior and middle tibiae with a sharp ridge in the middle of a shallow channel. Hind tibiae with a spur. Claws appendiculate. Length 6.2 mm; width 3.2 mm.

Type, male, U.S.N.M. no. 63137, collected "in banana trash from Panama."

Remarks.—Jacoby's description of *N. boliviana* agrees with this except that in his beetle the undersurface is entirely dark and the elytral markings are metallic green. This is the second species of the genus to be described from north of South America, the other, *N. inornata* Jacoby, also from Panama, being entirely pale with kidney shaped eyes.

Pseudodisonycha turquinensis, n. sp.
Fig. 1

About 6 mm in length, oblong oval, shining, nearly impunctate, pale yellow, the head, antennae, legs, except the basal half of femora, black, a deep blue wide transverse band at base of elytra and another equally wide below the middle, not reaching the apex.

Head with interocular space more than half its width, a large fovea on each side of vertex near eye with a few finer punctures about it; frontal tubercles bulging; a somewhat produced carina between antennal sockets extending down the short lower front; head entirely dark except for the pale labrum and the pale neck beneath the mouthparts. Antennae black, stout, third joint shorter than fourth, which is longest, remainder subequal and a little shorter than fourth. Prothorax not twice as broad as long with rounded sides and narrow margin; a small tooth at apical and basal angles; disk moderately convex with a slight median basal depression; entirely pale yellow. Scutellum pale yellow. Elytra with prominent humeri and deep intrahumeral sulcus, shining, very finely and not densely punctate; a wide deep blue band at base and also one below the middle, the latter not reaching the apex. Body beneath pale with the basal half of all femora pale, shining, a few pale hairs on the abdomen, coxal cavities open. Hind femora not as much thickened as in *Oedionychus*; a spur on hind tibiae; claws appendiculate. Length 6.4 mm; width 3 mm.

Type, female, U.S.N.M. no. 63138, collected by S. C. Bruner and C. H. Ballou on Pico Turquino, altitude 4,000–5,000 feet, Oriente Province, Cuba, July 20, 1922.

Remarks.—Because the markings resemble so much those of *Diabrotica pulchella* (Jacq. Du Val), this beetle was long concealed in the collection with that species. It is difficult to place in a genus. The hind femora while not greatly enlarged nevertheless are those of an alticid. The tibiae with the ridge on the upper side and the spur at the end, and the head with the fovea near the eye so characteristic of *Disonycha*, place it near that genus. The thorax, however, is not so broad as in *Disonycha* and does not have the wide anterior angles. There is unfortunately no male, and I have doubtfully assigned it to the genus *Pseudodisonycha* Blake.

ENTOMOLOGY.—*Two new species of* Rhyopsocus (*Psocoptera*) *from the U. S. A., with notes on the bionomics of one household species.* KATHRYN M. SOMMERMAN, Arctic Health Research Center, Public Health Service, Anchorage, Alaska. (Communicated by A. B. Gurney.)

The genus *Rhyopsocus* is currently placed in the family Psoquillidae according to Pearman's classification, 1936, or in Trogiidae following the classification of Roesler, 1944. If we assume that *Rhyopsocus*, *Deipnopsocus*, and *Rhyopsocopsis* are subgeneric categories in the genus *Rhyopsocus*, only one species of this genus is known to occur in the United States, *R.* (*Deipnopsocus*) *texanus* (Banks 1930) described from Brownsville, Tex. A second species, *R. eclipticus* Hagen, 1876, questionably from this country, was collected on Kerguelen Island in October 1874. The following comment is quoted from the original description: "The only specimen noticed during the stay of the Transit Party at Kerguelen was captured October 17, in-doors, and was mounted in balsam on a slide. Shortly before its capture some instrument boxes, brought from Washington and containing a quantity of packing straw, had been unpacked in the same room; a circumstance rendering the habitat of the insect very doubtful at the time. J. H. K." Hagen states that the antennae of this specimen were broken, one having eight basal segments and the other twelve, while an apical section of fourteen segments lay near by on the slide. It seems quite probable that the apical part was broken off the 8-segmented base instead of the 12-segmented one as he assumed.

The characteristics possessed by the species of this genus are: head short and oblique, labial palps 2-segmented, antennae 22-segmented, peg like sense organ on inner side of second segment of maxillary palp, Fig. 1, lacinia bifid, Fig. 2, ocelli usually completely developed in macropterous forms; wings variable in length, forewings rounded apically and possessing stout setae on veins and margin, usually a closed discal cell bounded by R and M and their derivatives (cell sometimes absent, especially in brachypterous forms), Cu usually shorter than Cu_2, in hind wing M not branched; tarsi 3-segmented, claws without preapical tooth, Fig. 3; paraprocts each with a mesad anal spine.

Two species of this genus came to my attention while collecting in the Southeastern States, one of which was taken indoors in small numbers in my house at Orlando, Fla. The latter was living year-round on the bedroom walls, the only walls covered with a water-base paint, in association with a species of the *Liposcelis bostrychophilus* complex and *L. entomophilus* (Enderlein, 1907). This species is of no apparent economic importance but because a study of some of the household psocids was being made at that time, preliminary observations were made on this one too. Unfortunately it was necessary to move before a detailed study of the bionomics could be made so the information is incomplete.

I am indebted to Mr. J. V. Pearman for comparisons and comments regarding these two species and *Rhyopsocopsis peregrinus* Pearman, 1929, and *Deipnopsocus disparilis* Pearman, 1931. Dr. P. J. Darlington examined the types of *eclipticus* and *texanus* and supplied information in answer to my questions. On learning that this paper was in preparation, Dr. A. B. Gurney kindly contributed for study the specimen he had collected in Texas. To each I extend my sincere thanks.

I have not seen specimens of the other species in this genus, and so my comments are based on the original descriptions and on observations made by others. These two new species apparently most closely resemble *R. eclipticus*, but the sex of the type of the latter is not known to me. Brachypterous individuals of these two new species are usually smaller than the macropterous forms and lighter in color. If such is generally true of the species in this genus, then these two species are smaller than *eclipticus*, the brachypterous form of which is larger than the macropterous forms of these two new species. Regardless of the sex of the

type of *D. spheciophilus* Enderlein, 1903, a Peruvian species, available information indicates that it differs from these two in several ways, the most noticeable being: color pattern, absence of setae along the margin of the anal lobe, and presence of rows of scales along the wing margin. Although there is some question concerning the presence of scales on the wings of *texanus* it is likely that the presence of the white hair on the head and legs of this species distinguishes it from these two.

Rhyopsocus bentonae, n. sp.

Figs. 1–12

Length of alcoholic specimens 1.15 to 1.6 mm including wings. Head and thorax of macropterous forms dark brown, antennae, legs and dorsal parts of terminalia light brown, abdomen pale yellow. Corresponding parts of brachypterous forms light golden brown to buff, with abdomen likewise pale yellow. Wing membrane almost hyaline, with a slight fumose tinge. There is considerable variation in wing venation, some veins having extra branches which may anastomose, but in general venation is as shown in Fig. 8.

Dorsal, posterolateral margin of male terminalia with two stout, curved, bluntly pointed and sparsely setose prongs; ventral surface of terminalia with a broad, thin, tail-fin-like flap (hypandrium?) which is a bit asymmetrical, Figs. 6, 11, 12.

Dorsal, anterior margin of female terminalia medianly expanded to form a quadrangular plate bearing a non-pigmented spot; anterior lateral limits of terminalia densely pigmented, much darker than lateral and apical margins of egg-guide; anterior margin of faintly pigmented subgenital plate convex, Figs. 4, 9, 10.

Holotype, macropterous male, Orlando, Fla., October 1953, ex culture, K. M. Sommerman. **Allotype,** same data. These are deposited in my collection. **Paratypes,** four specimens, a macropterous and brachypterous male and female, all same data as above, deposited in each of the collections of the following institutions or individuals: USNM, INHS, MCZ, P. J. Chapman, E. L. Mockford, and J. V. Pearman, and ten of each of the four kinds of individuals in my collection. The following additional distribution records are available, all from Florida: Daytona Beach, Nov. 2, 1941, ex dry palm leaves, A. H. Sommerman, ♂, ♀; Englewood, May 22, 1952, ex Flame vine, A. H. S. ♂; same, but March 13, 1953, ♂, 3 ♀; Orlando, Oct. 1953, ex cultures (original specimens from bedroom walls), many specimens, both sexes, nymphs of all instars, eggs on cotton; same, but July 7, 1954, 6♂, 2♀, 4N; Orlando, Feb. 15, 1954, ex bedroom walls, K. M. S. ♂, 5♀, 4N.

I take pleasure in naming this species after Jimmie Benton, who kindly furnished the materials for construction of the rearing racks. Her active interest in the rearing project concerning the household species was, indeed, stimulating and encouraging.

Rhyopsocus phillipsae, n. sp.

Figs. 13–17

Length of alcoholic specimens 1.1 to 1.5 mm including wings. Overall color similar to *bentonae*. Wings of macropterous forms, Fig. 13, with a more sharply defined, angulated anal lobe, much like that of *peregrinus*.

Dorsal, posterolateral margin of male terminalia with two thin, broad, rounded lobes; ventral surface of terminalia with exposed, median hooklike projection on anterior margin, Figs. 16, 17.

Dorsal, anterior margin of female terminalia medianly with slight expansion cephalad, or if pronounced, more rounded than *bentonae*; anterior lateral limits of terminalia faintly pigmented, much lighter than lateral and apical margins of egg-guide; anterior margin of lightly pigmented subgenital plate concave, Figs. 14, 15.

Holotype, brachypterous male, Valdosta, Ga., State College Campus, Apr. 23, 1955, ex bamboo sheaths, Sommerman and Phillips. **Allotype,** macropterous, same data. These are deposited in my collection. **Paratypes,** a brachypterous male and female, same data, deposited in USNM, brachypterous female, same data but ex ground cover, deposited in my collection. The following additional distribution records are available: Myakka S. Pk., Fla., June 7, 1952, ex Spanish moss, K. M. Sommerman, 3♂, ♀; Hayesville, N. C., Aug. 25, 1954, ex Boxwood, W. E. Snow, 2♂, 2N; same, but Oct. 26, 4♂, 10♀, 5N; 90 miles west of Orange, Tex., Oct. 8, 1951, beating trees, A. B. Gurney, ♂.

It is a privilege to name this species after Grace R. Phillips, who helped collect the type material and who has contributed other interesting specimens and records to my collection.

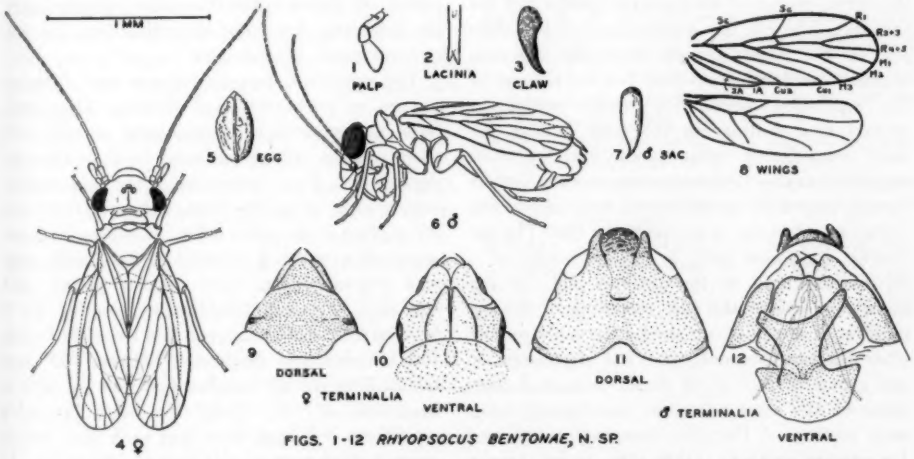
BIONOMIC NOTES

The following preliminary notes on the bionomics of *R. bentonae* were obtained from specimens reared under somewhat unnatural conditions. This rearing technique was used with good results for *R. bentonae* and these other household species: *Psoquilla marginepunctata* Hagen, 1865, *Psocatropos lachlani* Ribaga, 1899, *Ectopsocus* sp., and several species of *Liposcelis*. Some difficulty was encountered with the first instars of *P. lachlani*. The equipment consisted of small glass tubes 30 mm long by 9 mm in diameter, which had been cut from dental tubes. These were placed in half-inch wire mesh (hardware cloth) racks with screen bottoms, which were stacked in a quadrangular aquarium containing a little water below the racks. The aquarium was covered by a plastic tray with rounded corners which allowed an interchange of air and moisture, and the whole was kept at uncontrolled room temperature which fluctuated daily during September to mid-October when these preliminary observations on development were made, the extremes being 71° and 85°F.

The food was composed of the following ingredients (the recipe furnished enough medium to coat the ends of 200–300 corks): One teaspoon of dry solids, consisting of equal parts by volume of dried yeast, dehydrated mashed potato, starch and dehydrated skim milk, was added to one teaspoon of water and mixed well. Some of this mixture was smeared on the small end of each cork. The corks were put in a covered pan on a hot plate and heated until the medium was a pale brown. They were then stored in jars in the refrigerator.

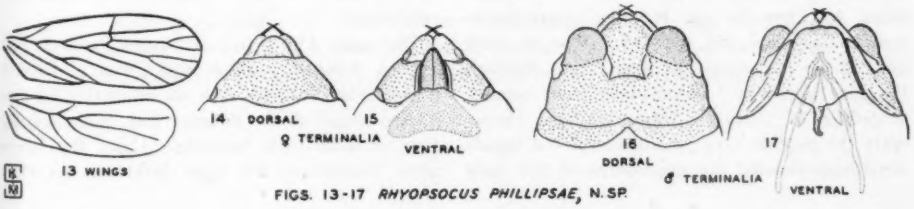
A cork containing the food was inserted in one end of a rearing tube, the psocids introduced and a thin cotton plug put in the other end. The tubes were then placed in the rearing racks. The medium softened in the moist atmosphere and the psocids ate it as well as the mold that grew on it. Eventually some tubes became infested with mites and the psocids retreated to the cotton plugs. Consequently food consumption was reduced and often either the psocids or the mites injured the psocid eggs. If a dead psocid were left in a vial containing more than one psocid, it was eaten by the others.

R. bentonae was an extremely active species,



FIGS. 1-12 *RHYOPSOCUS BENTONAE*, N. SP.

FIGS. 4-8 AND 13 TO SCALE, FIGS. 9-12 AND 14-17 ENLARGED TO SCALE, ALL SETAE OMITTED



FIGS. 13-17 *RHYOPSOCUS PHILLIPSAE*, N. SP.

often darting rapidly and making unexpected starts and stops. The courtship approaches were usually made by the male while rapidly vibrating his wings, which were held in a vertical position. If the female were in a receptive mood she would sometimes flit her wings in a vertical position for a fraction of a second, several times before mating. Occasionally the two psocids approached each other and rubbed palps but such antics were kept to a minimum or dispensed with entirely. Then the male approached the female head-on with his wings held vertically, quickly turned around and backed under the female as she raised her body to allow him to slip under her from the front. He curled the tip of his abdomen up and behind hers and when the genitalia were joined the male sidestepped 180° with the ventral side of the body twisted on the longitudinal axis at about 40° so that usually some of his tarsi were not on the substrate. Copulation lasted an hour on the average (eight timed matings varying from 41 to 73 minutes), and during this time there were prolonged rhythmic contractions of the abdomen of the male. Apparently a considerable amount of fluid was forced into the female abdomen because the dorsal prongs of the male terminalia and the ventral tail-fin-like flap eventually took a viselike grip on the female terminalia as her abdomen became considerably swollen. Toward the end of the copulation period the female sometimes walked around dragging the male behind. Almost immediately after separation the male deposited on the substrate a transparent, slightly curved (upward) carrot-shaped sac, which was drawn to a fine tip at the posterior end. The sac usually contained only a small amount of a transparent fluid at the anterior end. To my knowledge this is the first recording of the deposition of a copulatory sac by the male psocids after mating. Apparently it is not uncommon, in one group of psocids at least, because I have observed the same procedure immediately after each mating of *Psoquilla marginepunctata* and *Psocatropos lachlani*. Often the males turned around and ate part or all of the sac, or sometimes the females ate it. The approximate measurements of the sacs were 0.39 by 0.09 mm; these measurements were made through the glass tubes. Fig. 7 was sketched from memory according to averaged measurements. Apparently the psocids have preferences as the female sometimes resisted the approaches of the male and butted him with her antennae, and usually by the next day the antennae of the male were broken off to stubs if he were still alive. Occasionally on the following day the male was dead and partly consumed, but these "fights-to-the-finish" were not observed. However, one such resistant female was placed with another male and mating occurred shortly thereafter.

Mating occurred more than once. Two pairs were observed mating again 31 days after the first time. In one instance a male and female of *bentonae* were kept isolated from each other, but in the company of a *P. marginepunctata* individual of the opposite sex. Both sexes of *marginepunctata* made courting advances upon the opposite sexes of *bentonae* but their efforts were ignored. The two sexes of *bentonae* were put in the same tube for a short time on the 5th, 7th, 11th, and 20th days and each time mating occurred and a sac was deposited by the male. Limited data suggest that fertilized eggs may be deposited for a period of about two weeks at the most, after mating.

Information regarding length of the preoviposition period is lacking, but 9 pairs ranging in adult age from 3 to 6 days mated immediately when paired off. Seven of the 9 females deposited eggs the following day while the other two did not oviposit until 7 days later.

The eggs were deposited singly with little or no pre- or post-ceremonial activity. They were bare, not covered with excrement or silk, and there seemed to be a tendency to place them in depressions. They were most often laid on the cotton plug or on the food, but only rarely on the surface of the glass tubes. If mating had not occurred a reduced number of non-fertile eggs was deposited but they turned yellow and shriveled. The egg totals were recorded for 9 females from mid-October to late December when the temperatures fluctuated between 60° and 80° F. The average number laid was 74, with a maximum of 101. Under the more favorable conditions 5–7 eggs were laid each day, which suggests that perhaps as many as 400 eggs could be deposited by one female under optimum conditions.

The eggs, Fig. 5, are somewhat boat-shaped with a wrinkled chorion which has a distinct center ridge dorsally with an indication of two lateral ridges at the anterior end, each bearing four or more little tubercles. About four days after oviposition the eggs darkened. As they

approached maturity the eyes and also the egg burster, which was stretched across the front of the head could be seen through the shell. At hatching the nymph was ventral side up, with the head at the anterior end of the egg. Hatching occurred 8–10 days after oviposition. Air was swallowed at both eclosion and molting, a practice common among psocids.

The following information on development was obtained from group rearings since the eggs laid each day were allowed to hatch in the vial where oviposition occurred. Only the parents and, later, the newly emerged adults were transferred to a fresh vial each day; consequently the young from each daily "brood" grew up together. Although molts and instars could be recorded, one had to assume that the molting sequence was always the same as development progressed, but such is probably not the case. Most of the eggs hatched without any trouble and it was only after the continued absence of a male that non-fertile eggs were deposited.

The various observations on the nymphal stadia were based on a minimum of 17 and a maximum of 78 individuals. The average duration of the nymphal stage was 19.5 days, the first stadium being 2–5 days, usually 3. The duration of each of the second, third, fourth and fifth stadia ranged from 2–3 days and the sixth stadium was a little longer, 3–5 days, with an average of 4.

Based on observations from early October to January of nine mated pairs, the duration of the adult stage averaged 64 days for the females and 69 for the males with maximum periods of 86 and 89 days respectively. The sex ratio was 1:1. If males were present oviposition continued until a few days before death of the female, assuming that the few females under observation died of natural causes.

SUMMARY

Two new species of *Rhyopsocus* are described, and salient features illustrated for both *R. bentonae* and *phillipsae*. A rearing technique for household species is explained and notes on the bionomics of *bentonae* are given as determined from individuals reared under these somewhat unnatural conditions. Courting and mating are described, and the deposition on the substrate of an almost empty transparent sac by the male immediately after mating is noted. The life cycle is completed in a little more than a month, the duration of the egg stage being about 9 days and the nymphal period 20 days. The females laid an average of 74 eggs and adult life lasted approximately two months.

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Even if we resolve all matter into one kind, that kind will need explaining, and so on for ever and ever deeper and deeper into the pit at whose bottom truth lies, without ever reaching it, for the pit is bottomless.—O. HEAVISIDE.

MALACOLOGY.—*Mollusca dredged by the* Orca *off the Santa Barbara Islands, California, in 1951.* S. STILLMAN BERRY, Redlands, Calif. (Communicated by Harald A. Rehder.)

Through the kindness of Dr. Carl L. Hubbs, of the Scripps Institution of Oceanography, there was recently placed in my hands a collection of mollusks taken by himself, J. W. Sefton, and others, working from Mr. Sefton's research vessel, the *Orca*, off the Santa Barbara Islands, Calif., in the summer of 1951. Mollusca were not the items principally sought by this expedition, and since the collections were obtained in one of the more important areas in the Californian province where few precise studies in this field have been made it is most fortunate that in the press of the other important pursuits so many of them were eventually salvaged. By reason of our inadequate knowledge of the area the resulting list gains a significance quite out of proportion to the size of the collection. It is of further interest in that it includes a number of infrequently reported or little-known species, several of which constitute important extensions of range. In the first part of the paper each station from which mollusks have been submitted is cited in turn, and an annotated list of the species obtained is appended. These include dredge hauls from seven stations having recorded depths from 11 to 58 fathoms. The richest of these was H51-254, in 46 to 58 fathoms, north of Anacapa Island, whence no less than 59 species are here recorded. The second part of the report covers the formal descriptions of the three species obtained which are recognized as new.

The author is happy to express his appreciation of the kindness of both Mr. Sefton and Dr. Hubbs in supplying the material studied. The assistance of Ellis Rich, of the College of Medical Evangelists, Loma Linda, Calif., who made the photographs used in the accompanying illustrations, is likewise gratefully acknowledged.

ANNOTATED LIST

Stations H51 240 and 241 (pipe-dredge), 11 to 20 fathoms, lat. 34°01′45″ to 34°02′20–35″ N., long. 119°41′40″ to 119°42′07–22″ W., off Pelican Bay, Santa Cruz Island, June 29, 1951.

Lima hemphilli Hertlein and Strong: 3 adolescents.

Cardium (*Trachycardium*) *quadragenarium* Conrad: 1 juvenile.

Calliostoma gloriosum Dall: 4 adolescents.

Calliostoma supragranosum Carpenter: 1.

Pteropurpura carpenteri (Dall): 1 adult, 2 juveniles. It appears not impossible that the oldest name for this species is *Murex macropteron* Deshayes (1839:360; 1841:pl. 38; 1843:606). This was originally described without citation of locality. Its subsequent history has been a checkered one. Poirier (1883:93) attributed it to Japan, but I have found no confirmation of an Oriental habitat in the writings of any recent worker in that field. Dall (1889:201) thus identified two specimens dredged off Cape Hatteras, N. C. This western Atlantic species has since been separately recognized as *M.* (*P.*) *bequaerti* Clench and Farfante (1945:40). Unhappily I have only once seen the original figure of *M. macropteron*, and the holotype has never been refigured unless, perchance, it be the shell figured under this name by Reeve (1845: Murex pl. 27, sp. 123) and Sowerby (1880: Murex pl. 11, fig. 111). These figures, both drawn by Sowerby, are so nearly alike as almost certainly to have been made from the same shell, that in Reeve being by all odds the better executed and more detailed. That these are excellent representations of the Californian shell subsequently named *carpenteri* by Dall is at once apparent when shell and drawing are placed side by side. Should they then have been correctly affiliated by the iconographers with Deshayes' species, there would seem little doubt where that century-old enigma will finally come to rest. As I intend dealing with this situation much more fully in a forthcoming contribution, no further elaboration of the case history seems necessary here.

Station H51-243 (pipe dredge), 43 to 45 fathoms, lat. 34°02′37″ N., long. 119°41′, 35 to 05″ W,. northeast of Pelican Bay, Santa Cruz Island; mud bottom; June 29, 1951.

Nucula (*Nucula*) *tenuis* (Montagu): 23, nearly all mature.

Nucula (*Acila*) *castrensis* Hinds: 114 of various ages, and 2 valves.

Nuculana taphria (Dall): 1 valve.

Nemocardium centifilosum (Carpenter): 5 immature.

Compsomyax subdiaphana (Carpenter): 3½.

Tellina (*Merella*) *carpenteri* Dall: 1.

Dentalium neohexagonum Pilsbry and Sharp: 2.

Turritella orthosymmetra Berry: 1 (plus a fragment).

Bittium sp. (nov. ?): 1. This can be referred to no described species known to me, but in so difficult a genus as *Bittium* a new species should be distinct indeed to justify its foundation upon a single specimen.

Crepidula adunca (Sowerby): 1 bleached shell.

Megasurcula carpenteriana (Gabb): 1 juvenile. Probably referable to the form *tryoniana* (Gabb).

Turbonilla (*Mormula*) *regina* Dall and Bartsch: 2. These can presently be identified in no other way, although the larger has three brown bands on the body whorl not specified in the original description or in Bartsch's key.

Acteocina intermedia Willett: 2. This and *eximia* (Baird) seem not too happy in *Acteocina*. I fail to see why either of them ever need be confused in any way with *A. culcitella* (Gould).

Station H51-251 (pipe dredge), 162–150 feet (26–27 fathoms), lat. 34°00′38″ to 20″ N., long. 119°30′35–13″ W., Anacapa Passage; gravel bottom, with some stones; July 2, 1951. Vegetation: *Callophyllis, Drouetia, Reticulobotrys, Lithothamnia*, predominant.

Pecten (*Pecten*) *diegensis* Dall: 2 not quite mature. Both carried *Capulus*, q.v. infra.

Oldroydia percrassa (Dall): 1 juvenile.

Dendrochiton (?) sp.: 1 juvenile.

Capulus californicus Dall: 3 immature. Two of these *in situ* on *Pecten diegensis*, the third loose in jar.

Trivia (*Pusula*) *ritteri* Raymond: 1. Surface of shell somewhat altered by preservative used.

Bursa californica (Hinds): 3. Very small for the species, but of mature aspect.

Odostomia (*Evalea*) *santarosana* Dall and Bartsch: 1. The specimen seems best referable to this little-known species. The color, however, is much paler than would be inferred from its original description as "light olive."

Station H51-252 (pipe dredge), 174–190 feet (29–31.5 fathoms), lat. 34°00′10″ N., long. 119°27′35–05″ W., Anacapa Passage; gravel bottom, with stones; July 2, 1951. Vegetation: *Drouetia, Reticulobotrys, Lithothamnia*, etc.

Terebratulina unguicula (Carpenter): 11. The specimens were taken adhering to a small piece of coral. Not a mollusk, but included for the sake of the record.

Chlamys hastatus (Sowerby): 1.

Diplodonta cf. *subquadrata* Carpenter: 2 adolescents. Californian shells are more acutely beaked and possess a much more strongly developed dentition than any of the west Mexican mainland specimens examined by me. The question of their identity might well be reinvestigated by someone having access to more complete series than I have seen.

Semele aff. *incongrua* Sowerby: 1, probably immature.

Acmaea funiculata Carpenter: 1 juvenile shell, remarkable in that a sharply ribbed initial stage is abruptly succeeded by a stage in which the ribs become in large degree obsolescent. For a finely detailed discussion of this still somewhat enigmatic species see Hanna and Smith, 1931:21.

Astraea (*Pachypoma*) *inaequalis rutila* (C. B. Adams): 2. The specimens are small for the species. I am unable to detect any material difference between this form and *A. i. montereyensis* Oldroyd. Carpenter's suggestion that *rutila* belongs under *A. undosa* (Wood) I believe to be erroneous.

Calliostoma annulatum (Martyn): 2 juveniles. Those who reject Martyn's names can save this one by quoting it as of Humphrey (1786:101).

Vermicularia fewkesii (Yates): 1.

Trivia (*Pusula*) *ritteri* Raymond: 1. A perfect example of this lovely chaste species.

Nassarius insculptus (Carpenter): 1.

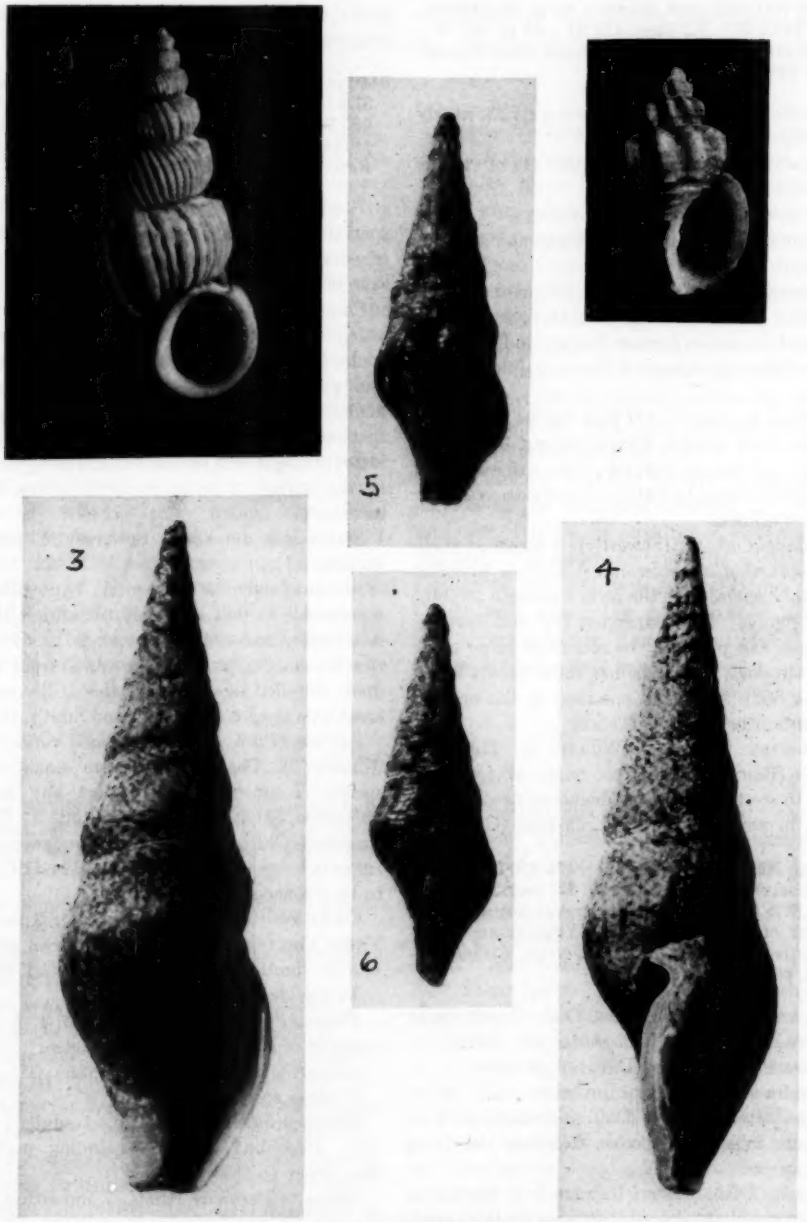
Fusinus sp.: 1 adolescent.

Pseudomelatoma sticta, n.sp.: 1 adult; 1 immature. Described in the concluding portion of this paper (p. 156).

Conus californicus Hinds: 7 immature.

Station H51-254, 46–58 fathoms, lat. 34°03′05″ to 45″ N., long. 119°26′02″ to 25′28″ W., ca. 2½ miles N. of W. end of Anacapa Island; July 2, 1951.

This was the richest in Mollusca of any haul



FIGS. 1–6.—1, *Epitonium* cf. *lowei* (Dall), mature shell taken in 46–58 fathoms, north of west end of Anacapa Island, Calif., × 2.6; 2, *Admete seftoni*, n.sp., holotype, taken in 46–58 fathoms, north of west end of Anacapa Island, Calif., × 4.25; 3, *Pseudomelatoma sticta*, n.sp., ventral aspect of holotype, taken in 26–27 fathoms, Anacapa Passage, Calif., × 3.5; 4, *P. sticta*, n.sp., lateral aspect of holotype, same scale; 5, *P. sticta*, n.sp., ventral aspect of the immature paratype, × 3.5; 6, *P. sticta*, n.sp., lateral aspect of same specimen; same scale.

made, both as to species and as to number of individuals.

Nucula (*Acila*) *castrensis* Hinds: 105½.

Nuculana hamata (Carpenter): 1½.

Modiolus pallidulus (Dall): 1.

Cardita (*Cyclocardia*) *longini* Baily: 13½. For this name and the reasons impelling rejection of two prior names for the species see Baily, 1945.

Pseudochama granti Strong: 1 juvenile valve. The specimen shows the larval shell with exceptional distinctness.

Nemocardium centifilosum (Carpenter): 14 juveniles and adolescents.

Tellina (*Moerella*) *carpenteri* Dall: 6.

Spisula cf. *planulata* (Conrad): 1 right valve.

Hiatella arctica (Linné): 2 juveniles.

Cuspidaria (*Cardiomya*) *californica* Dall: 1.

Leptochiton oldroydi (Dall): 1. A distinctive species, although one of the smallest of west American chitons.

Puncturella cooperi Carpenter: 1. This example clearly displays the curious punctations which characterize the shells of a number of species in this genus.

Margarites (*Lirularia*) *acuticostatus* (Carpenter): 2 shells.

Margarites (*Lirularia*) *pedroanus* (Arnold): 3. The Californian species of *Lirularia* are exceedingly difficult of satisfactory disposition. The determinations here suggested are believed to be about as close as is possible in the absence of a thoroughgoing revision.

Solariella peramabilis (Carpenter): 4, plus 3 empty shells.

Cidarina cidaris (Carpenter): 1 half-grown shell.

Calliostoma annulatum (Martyn): 1 juvenile bleached shell.

Calliostoma turbinum Dall: 1.

Liotia farallonensis A. G. Smith: 1. This rare species has hitherto been known only from the vicinity of the Farallon Islands (see Smith, 1952:385). A fine mature example now provides an important extension of range.

Homalopoma sp.: 1. A thoroughly puzzling specimen, the closer determination of which is postponed pending the aquisition of additional material.

Turritella cooperi Carpenter: 10 shells, representing a form in which the spiral keels are quite strongly developed.

Turritella orthosymmetra Berry: 6 shells. These are badly bleached but are apparently referable here.

Bittium sp. indet.: 7 (plus 15 shells). This is a form rather close to *B. subplanatum* but with flatter whorls and more regular tuberculation. It is possibly undescribed, but for the time being I refrain from adding another name to this genus of many and difficult species.

Bittium sp. indet.: 1 bleached shell. Similar to the preceding but much more sparsely and coarsely tuberculate.

Bittium cf. *rugatum* Carpenter: 5 bleached shells.

Seila montereyensis Bartsch: 1. Altitude of shell exclusive of missing apex, 14.2 mm.

Epitonium (*Nitidiscala*) *indianorum* (Carpenter): 1.

Epitonium (*Asperiscala*) cf. *lowei* Dall (Fig. 1): 1. This superb example is remarkable for its very numerous and crowded, strongly reflexed, coronate costae, a few of which become much thickened and with their exaggerated reflexed portions also much wider than the ordinary costae, thus taking on the character of true varices and to this extent casting doubt on current interpretations of simple repetitive costae as varices. The costae number 30–31 on each of the last two whorls and 28–29 on whorls higher up the spire. The inadequately known *E. lowei* is stated to have 26–27 costae, none of which is described as varically thickened, but the recorded specimens are much smaller with an altitude of only 7 mm. (see Dall, 1906:44; 1921:214, pl. 6, fig. 11), and I am unable to find any really trenchant characters whereby they might be distinguished from the apical whorls of this shell. The *Orca* specimen measures: altitude 21.6; maximum diameter 10.6; altitude of aperture 6.4 mm.; extreme apex decollated.

Balcis (*Balcis*) *micans* (Carpenter): 1.

Balcis (*Vitreolina*) *titubans*, n.sp.: 1. Described in the concluding section of this paper (p. 154).

Calyptraea contorta (Carpenter): 1 juvenile shell.

Crepidula cf. *onyx* Sowerby: 1 bleached shell. An example of a small narrow form such as one sometimes sees on a *Turritella* or *Olivella* shell.

Natica (?) sp. indet.: 3 small shells. These have much the aspect of *Cryptonatica*, but as there is at least one species in the area with a tight umbilical callus of this type, yet having a horny operculum, they must for the time being be left unplaced.

Polinices (*Euspira*) *draconis* Dall: 1.

Trivia (*Pusula*) *ritteri* Raymond: 1 immature.

Neosimnia catalinensis (Berry): 1. A perfect although not quite typical adult example of this rarely taken species.

Ocenebra clathrata (Dall): 5 shells.

Ocenebra (?) sp.: 1 shell.

Boreotrophon triangulatus (Carpenter): 1 shell.

Boreotrophon aff. *bentleyi* Dall: 2 (plus 1 shell). These seem quite similar to *B. bentleyi* and may represent a form of it, but the shell is smaller, more compact, and obscurely spirally striate.

Mitrella tuberosa (Carpenter): 5 shells.

Amphissa reticulata Dall: 2 shells.

Amphissa undata Carpenter: 198 (plus 70 shells). By far the most abundant species in the haul.

Nassarius aff. *perpinguis* (Hinds): 1 shell. A puzzling shell, similar in general aspect to *N. perpinguis*, but much higher and with a different and peculiar sculpture, especially on the spire. More material will be needed for its satisfactory disposition.

Nassarius insculptus (Carpenter): 2 (plus 6 shells).

Olivella baetica Carpenter: 1 bleached shell.

Mitra (*Atrimitra*) *idae* Melville: 1 shell. A hermit-crab shell of fair size.

Admete cf. *gracilior* Carpenter: 2. These represent a form close to typical *gracilior*, differing chiefly in the more acute shoulder tuberculation and in the possession of but 8 axial ribs on the body whorl. It may eventually prove nameable as a further-evolved living race of the earlier species.

Admete, n.sp.?: 2. These appear quite close to a fossil form which the author has in MS.

Admete seftoni, n.sp.: 2. Described in the concluding section of this report (p. 155).

Elaeocyma empyrosia (Dall): 4 (plus 1 doubtful bleached shell).

Antiplanes perversus (Gabb): 5. These are of medium size only.

Antiplanes (*Rectiplanes*) sp.: 2. Surface corrosion is here too great to permit certain determination without additional material.

Lioglyphostoma crystallina (Gabb): 1 (plus 3 shells): Although there are obvious discrepancies with Dall's figure (1921:214, pl. 6, fig. 4), there is reasonable agreement with the original description of Gabb. Relative age may conceivably explain the differences.

Mangelia (*Kurtzia*) *roperi* Dall: 1 shell.

Turbonilla (*Pyrgolampros*) sp. indet.: 1. A long slender species which can not at present be affiliated with any of the described forms.

Turbonilla (*Mormula*) *regina* Dall and Bartsch: 5. Of various ages and sizes, several showing spiral bands on the body whorl. Altitude of largest shell, 21.0 mm.

Acteocina intermedia Willett: 1 (plus 7 shells).

"Retusa" harpa (Dall): 1.

Cylichna diegensis Dall: 2.

Station H51-260 (pipe dredge), 86–94 feet (ca. 14–16 fathoms), west of Ford Point, Santa Rosa Island. Vegetation: abundant red and brown algae; July, 4, 1951.

Glycimeris corteziana Dall: 1.

Cardita (*Cyclocardia*) *longini* Baily: 13½.

Chama pellucida Conrad: 1 damaged immature.

Dentalium sp.: 1.

Calliostoma splendens Carpenter: 3.

Bittium attenuatum Carpenter: 1.

Balcis (*Vitreolina*) *thersites* (Carpenter): 1 immature.

Ocenebra clathrata (Dall): 1.

Ocenebra (?) cf. *munda* Carpenter: 1 imperfect shell.

Mitrella carinata (Hinds): 98. Small for the species, but nearly all mature.

Nassarius cooperi (Forbes): 4 shells.

Conus californicus Hinds: 7, mostly immature.

DESCRIPTIONS OF NEW SPECIES

Balcis (Vitreolina) titubans, n. sp.

Figs. 7, 8

Shell of fair size for a Californian member of the genus, solid, smooth, polished, basally robust, with an acute, rapidly tapering, doubly flexed spire; apex moderately tipped dorsad, with the body of the shell strongly diverted to the right. Whorls 10 to 11, the first translucent, the second less so, and those succeeding opaque milky white, very slightly swollen above the tightly appressed and barely indented suture; last whorl rounding smoothly into the full and moderately produced base. Sculpture wanting except for the distinct varical grooves, which, beginning dorsally on the sixth whorl, descend the shell in narrowly stepped obliquely protractive alignment, each groove producing an angular downward dip in the suture as it leaves it, the series terminating just back of the lip; final whorl without a varix and without a sutural indentation. Aperture a trifle over one-quarter the altitude of the shell, narrowly pyriform, its posterior angle acute, rounded and slightly pro-

duced in front; parietal wall barely convex, forming a widely obtuse angle where it adjoins the nearly straight, narrow, and somewhat oblique columella, the whole covered by a moderately thick, sharply bounded callus which is slightly expanded in front and appressed against the base of the shell; output lip entire, gently sinuate below the suture, thence rather weakly produced peripherally; from the periphery the lip rounds smoothly back and inward to its narrow expansion into the columellar thickening.

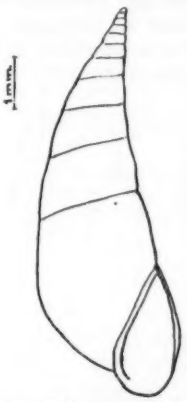


FIG. 7.—*Balcis* (*Vitreolina*) *titubans*, n. sp., camera-lucida outline of holotype; much enlarged.

Measurements (of holotype): Altitude 7.4; maximum diameter (est.) 2.7; altitude of aperture (to suture) 1.87; diameter of aperture (edge of columellar lip to outer lip) 0.9 mm.

Holotype: Berry Collection no. 23624.

Type locality: 46–58 fathoms, ca. 2½ miles north of Anacapa Island, Calif.; one example, *Orca*, July 2, 1951.

Commentary: The distortion of symmetry in *B. titubans* is one of the most extreme seen in any of our species. It is much larger than the more or less similar *B. grippi* (Bartsch) of the same region, and it is both more robust and more eccentric in form than either that species or the more northern and likewise similar *B. columbiana* (Bartsch).

The specific name is the present participle of the Latin *titubo*, I stagger.

Admete seftoni, n. sp.

Figs. 2, 9

Shell small, robust, with 5 to 5¼ whorls; spire short, acutely conic, with sunken channeled sutures; nuclear whorls rounded, more or less corroded in examples studied, but apparently smooth, subcarinate above, and at the beginning partially immersed; subsequent whorls strongly convex, slopingly subtabulate above, with 8 to 9 strong, moderately retractive, axial ribs, and with a strong spiral cord on the angle as well as another below it a little more than halfway to the suture; between these two primary spirals a third cord shortly arises, followed sometimes on the penultimate whorl by a fourth more slender cord below these and a fifth above the shoulder cord; body whorl more narrowly and less distinctly tabulate than the preceding whorls, bearing about 9 axial ribs, the last of which back of the aperture is somewhat obsolescent, and the above-mentioned 4 or 5 spiral cords, the most emphatic of these being the strong cord on the periphery separated by quite a wide space from a similar cord farther down the whorl, while below on the base are 4 lesser spirals of diminishing strength, the subperipheral and two posterior basal threads penetrating the aperture parietally; entire surface including the cords delicately spirally striate and more crudely axially threaded; axial ribs subtuberculate where crossed by the spiral cords, the nodules being best developed on the earlier whorls Aperture ovate, rounded posteriorly, more pointed, though very obtusely so, in front; outer lip thin, smooth within, although the external cords shine through to give somewhat the effect of a liration; lip margin ascending a little from the suture, then roundly descending into the very short, widely open canal; inner lip covered by a wash of callus which is thin, well expanded, and closely applied parie-

FIG. 8.—*Balcis* (*Vitreolina*) *titubans*, n. sp., camera-lucida outline of holotype as seen from right side; same scale as Fig. 7.

tally, but heavier and lip-like at the columella where it becomes appressed over the very narrow and impermeable umbilical chink; columella sloping very slightly inward and furnished with two fairly strong oblique plications.

Measurements (of holotype): Altitude 9.4; maximum diameter 5.8; altitude of aperture 5.4; maximum diameter of aperture (edge of columellar flare to margin of outer lip) 3.5 mm.

Holotype: Berry Collection no. 23679. *Paratype:* Berry Collection no. 23629.

Type locality: 46–58 fathoms, ca. 2½ miles North of Anacapa Island, Calif.; 2 examples, Orca, July 2, 1951.

Commentary: This very attractive little species is closely similar to no described form known to me. Its large body whorl, low-conic spire, deep suture, and strong axial plication afford a combination of characters which sets it well apart. In general form it somewhat resembles the considerably larger Alaskan species which currently passes for *A. couthouyi* (Jay), but it differs sharply in nearly every detail.

The species is dedicated to Joseph W. Sefton, of San Diego, master of the *Orca*.

Pseudomelatoma sticta, n. sp.

Figs. 3–6

Shell of moderate size, elongate-fusiform, with tall, sharply conic spire; whorls 9+, slightly constricted in front of the suture, the anteriorly thrust periphery smoothly convex; suture sharply defined; first nepionic whorl and a quarter smooth, mammillate; succeeding whorl rather abruptly showing about 6 fairly sharp spiral grooves and about 10 strong protractive axial ribs which do not cross the fasciole; although remaining strong for yet another whorl or so, all this sculpture gradually tends thereafter to obsolescence except at the periphery where the ribs persist as low rounded knobs, the number of which to a whorl remains about the same until the body whorl is reached, when the entire later portion becomes practically smooth; spiral grooving particularly strong on the base of adolescent shells, but even in this region represented only by traces on such a fully mature shell as the holotype. Aperture elongate-pyriform, about 38 percent of the height of the shell, widest posteriorly, its posterior angle acute; outer lip moderately thick, sharp-edged, unarmored, produced anteriorly into the short, open, very slightly recurved canal; inner lip and columella smooth, weakly sigmoid, covered by a rather thick callus the outer boundary of which is a rather sharp groove in the adolescent shell and a low ridge in the adult. Anal notch distinct, shallow, subjoining the suture; fasciole rather wide, marked principally by the inbowed lines of growth. Color generally a light golden brown, everywhere speckled with small, rounded, discrete, dark brown spots, in some areas showing a tendency to a certain regularity of arrangement; the holotype also shows a large, conspicuous, blackish brown spot over and immediately in front of the inner lip and there is considerable dark staining or a suggestion of banding in the outer wall of the chamber.

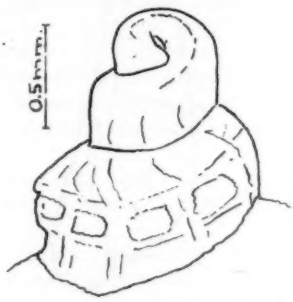


FIG. 9.—*Admete seftoni*, n. sp., camera-lucida sketch of apex of paratype; greatly enlarged.

Measurements: Holotype—altitude 29.5; maximum diameter 9.2; altitude of aperture 11.2; diameter of aperture 4.4 mm. Paratype—altitude 17.3; maximum diameter 6.5; altitude of aperture 7.3, diameter of aperture 2.8 mm.

Holotype: Berry Collection no. 23785. *Paratype:* Berry Collection no. 23584.

Type locality: 26–27 fathoms, Anacapa Passage, Calif.; 2 specimens, *Orca*, July 2, 1951.

Commentary: Even amid the graceful family of the turrids this is a trimly elegant species, characterized by the down-sagging (or anteriorly thrust) noded convexity of the whorls comprising the spire, by the eventual obsolescence of the originally sharp axial and spiral sculpture, and by the neatly speckled color pattern. These features separate it from all other members of the genus *Pseudomelatoma*, with which its present affiliation can be only tentative in the absence of any knowledge of the animal and particularly of its radula. The shells of both holotype and paratype were almost completely covered by a heavy whitish bloom, apparently limy and perhaps algal,

which proved exceedingly difficult of even incomplete removal.

The specific name is the Latin *stictus*, dotted, and has reference to the speckled color pattern of the shell.

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LOW-TEMPERATURE ALIGNMENT OF RADIOACTIVE NUCLEI PROVIDES DATA ON NUCLEAR DISINTEGRATION

Low-temperature research at the National Bureau of Standards has succeeded in aligning the nuclei of three radioactive elements—cerium-139, cerium-141, and neodymium-147. These results were achieved by cooling samples of the three materials to within a few thousandths of a degree of absolute zero. At such temperatures the effects of thermal agitation become so small that atomic nuclei can line up in a given direction within the crystal lattice. A corresponding directional effect can then be observed in the emitted radiation.

The nuclear alignment experiments[1] were carried out by Drs. E. Ambler and R. P. Hudson, of the Bureau staff, in cooperation with Dr. G. M. Temmer, of the Carnegie Institution of Washington. Initial phases of the work were sponsored by the Office of Naval Research.

Low-temperature alignment of nuclei promises to provide a new tool for studying the processes of nuclear disintegration. The nucleus may be regarded as a magnetic top spinning about an axis. If this spinning magnet is radioactive, the orientation of the spin axis will determine the directions in which the nucleus emits radiation. Normally, when nuclei are randomly oriented, a radioactive specimen emits gamma rays with equal intensity in all directions. However, when the nuclei are aligned, the intensity of gamma radiation varies with angle of emission. By measuring the degree of this directional effect, valuable information can be obtained concerning the decay scheme of the nuclei, and an insight can be gained into the mechanisms controlling such processes. For example, the magnetic moment of the nucleus can be determined as well as the changes in angular momentum accompanying the emission.

In the Bureau's experiments, radioactive nuclei were incorporated into certain inorganic crystals formed by the elements studied, which were then cooled to temperatures as low as 0.003°K. Nuclear alignment was observed by measuring the angular distribution of the intensity of the gamma radiation emitted by the crystals.

Inasmuch as the crystals used were paramagnetic, the necessary low temperatures could be conveniently produced by the method of adia-

[1] For further details, see *Alignment of cerium-141 and neodymium-147 nuclei*, by E. AMBLER, R. P. HUDSON, and G. M. TEMMER, Phys. Rev. **97:** 1212. 1955; and *Alignment of three odd-A rare earth nuclei*, by the same authors, ibid. **101:** 1096. 1956.

batic demagnetization. In this method a paramagnetic crystal is first magnetized by a powerful magnet. The resultant heat of magnetization produced in the crystal is removed from the system. Then when the magnetic field is turned off, the reverse effect occurs, and the temperature of the crystal falls to a very low value. The specimen soon begins to reheat, of course, but if due care has been taken to reduce heat leaks, the rate of heating is sufficiently slow to allow enough time for measurements.

In the Bureau's experiments a magnetic field of about 23,000 oersteds was used. A radioactive crystal containing the element under study was mounted on a thermally insulating support within a glass tube containing a small amount of "exchange gas" (helium at low pressure). The exchange gas provided thermal contact between the crystal and a surrounding bath of liquid helium boiling at about 1°K under reduced pressure. The liquid helium bath was protected against heat influxes by a Dewar vessel, which was in turn surrounded by liquid nitrogen.

When the magnet was switched on, the heat of magnetization was conducted from the crystal through the exchange gas to the liquid helium. This kept the temperature of the crystal from rising. The crystal was then isolated thermally by pumping the exchange gas away. Thus, when the magnet was turned off, the temperature of the crystal fell appreciably.

To observe nuclear alignment, the apparatus was then quickly moved into position between two scintillation counters, and the intensity of gamma radiation was measured along two different directions. As the crystal warmed up, a gradual decrease in the degree of alignment was observed. Finally, when the temperature reached 1°K, the nuclei were again found to be randomly oriented. This process was repeated a number of times in order to provide sufficient data to reduce the effects of random variation. From the data, basic information was obtained on the nucleus and its radioactive decay.

During each run the temperature of the crystal was monitored. This was done by measuring its magnetic susceptibility, which had previously been determined as a function of temperature by other investigators.[2]

The physical processes which give rise to nuclear alignment may be described as follows. Interaction with the electric fields within the crystal causes the electronic magnetic moment of certain atoms to line up either parallel or antiparallel to a certain crystallographic direction. Then at very low temperatures, where thermal agitation is much less, the coupling between the atomic magnetic moment and the nuclear magnetic moment is strong enough to allow the nuclei also to be pulled into alignment. This coupling cannot begin to overcome the forces due to thermal motion, however, until the temperature falls well below 1°K.

The anisotropic angular distribution of gamma rays from the aligned nuclei can be explained by considering angular momenta. Since the angular momenta of the parent and daughter nuclei as well as that carried away by the gamma ray are fixed by nature, it follows from the principle of conservation of angular momentum and from radiation theory that definite restrictions are placed upon the pattern of gamma-ray emission. The phenomenon is analogous to the radiation from a radio antenna, where anisotropic emission patterns are also observed. This close relationship between gamma radiation and angular momentum makes it possible to utilize gamma-ray intensity data as a basis for deductions concerning the angular momentum of the parent nucleus and the changes occurring during radioactive decay.

Work in this general field is continuing at the Bureau. Attention is now being directed to low-temperature methods of polarizing, rather than aligning, nuclei. Stable nuclei can be employed in experiments of this kind, and a larger number of different nuclei can be studied. The Bureau hopes to obtain additional data of value both to cryogenics and nuclear physics.

[2] DANIELS, J. M., and ROBINSON, F. N. H. Phil. Mag. **44**: 630, 1953.

The man who makes no mistakes does not usually make anything.
—EDWARD J. PHELPS

ZOOLOGY.—*A new fairy shrimp from western United States, with notes on other North American species.* RALPH W. DEXTER, Kent State University, Kent, Ohio. (Communicated by Fenner A. Chace, Jr.).

Recent studies on the fairy shrimps (Crustacea; Anostraca) of North America have brought to light some new and interesting records worthy of publication. One new species collected from Nevada, Washington, and California is described. The known geographic range of nine species is extended considerably by the acquisition of some new locality records. Additional records of two species of fairy shrimps living in the same pond are given and the seasonal occurrences of *Eubranchipus serratus* and *E. vernalis* in certain ponds studied in east central Illinois during the spring seasons of 1951–1955 inclusive are outlined in detail. This report continues the studies published in an earlier paper (Dexter, 1953).

Specimens of Anostraca collected by Robert S. Bray which are mentioned in this paper were sent to the writer by Dr. Folke Linder of Sweden. Specimens sent from the U. S. National Museum were obtained through the courtesy of Dr. Fenner A. Chace, Jr., curator of the Division of Marine Invertebrates. To these men and to the others named below who contributed specimens for this work my heartiest thanks are given.

Family BRANCHINECTIDAE

Branchinecta mackini, n. sp.

MALE (Figs. 1–4): Total body length, including cercopods, 16–25 mm. First antennae 4.5 mm. Second antennae 8.0 mm, consisting of two articles of equal length. Proximal article contains at its base a spur 0.4 mm long with minute spinules on it. Near the lower end of the same article are 3 or 4 inconspicuous spines well spaced along the lower medial surface. The distal article is gently curved, somewhat flattened, and the end is not recurved. There is no antennal appendage and no frontal appendage. Eye stalk 0.8 mm in total length. Penes 1.0 mm in length with a process 0.2 mm long and two swollen, spinous areas near the tip. There are seven postgenital segments. Cercopods are 2.0 mm in total length, gradually taper to a sharp point, and are fringed with setae 0.2–0.4 mm long. Swimming appendages are 2.5–4.0 mm long, with one proepipodite and one epipodite.

FEMALE (Figs. 5, 6): Total length, including cercopods, 16–25 mm. First antennae 3.2 mm. Second antennae 1.3 mm in length, swollen with a short, sharp point at the end. Eye stalk 0.8 mm in total length. Ovisac 6.5 mm in total length; 1.3 mm in greatest diameter. There are seven postgenital segments. Cercopods and thoracic swimming appendages are like the male.

This species resembles most closely *Branchinecta shantzi* Mackin, 1952. However, *B. mackini* has a pointed spur at the base of the second antennae of the male instead of a rounded knob, the spines along the medial margin are not concentrated and are not on a swollen prominence, and the tips of the male antennae are not recurved as they are in *B. shantzi*.

Specimens were collected by Dr. Ira La Rivers from a playa pond 15 miles north of Reno in Washoe County, Nev., on February 16 and June 9, 1940 (eight males and two females, seven males and one female, respectively), and again from a playa pond south-southeast of East McNett Place, Fish Lake Valley in Esmeralda County, Nev., on March 26, 1951. Seven males and 14 females were collected at that time from which the holotype and allotype have been selected. Dr. R. H. Whittaker and his student C. W. Fairbanks collected many specimens from a large shallow pond some 40–50 hectares in area at Alkali Lake, Grand Coulee, Wash., on May 15, 1949. Dr. Arthur S. Lockley collected some from Bicycle Dry Lake near Barstow, Calif., in November 1955.

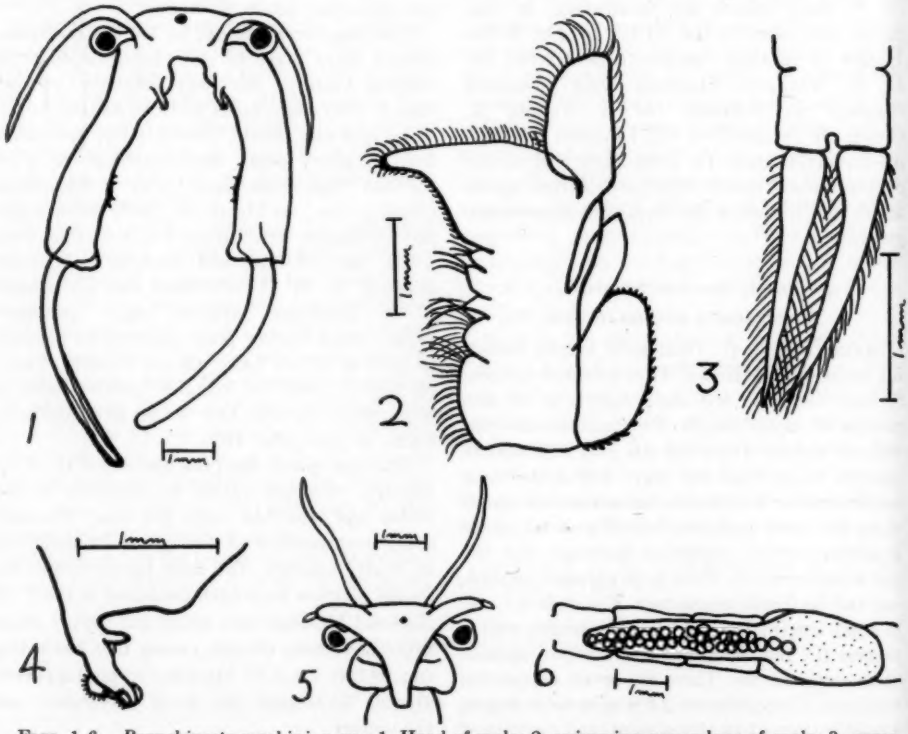
This new species has been named for Dr. J. G. Mackin, who first called its attention to the writer and who has made the most thorough study and revision of the genus Branchinecta in North America. The male holotype and the female allotype have been deposited in the U. S. National Museum (nos. 99216 and 99217). Paratypes have been divided among that institution (no. 99218), Dr. J. G. Mackin, Dr. Ira La Rivers, Dr. N. T. Mattox, Dr. R. H. Whittaker, and the writer.

NEW RECORDS OF GEOGRAPHICAL DISTRIBUTION OF ANOSTRACA

Since the publication of my previous paper outlining the known geographical distribution of certain species of fairy shrimps in North America, some new field records have come to hand which extend the known range of nine species and give additional locality data on some uncommon species.

The distribution of *Polyartemiella hazeni* (Murdock) has usually been given in the literature in very general terms as "the coastal plains of Alaska and Yukon Territory." Few specific records on those plains have ever been published. For that reason two which have come to hand recently are given here. Dr. N. T. Mattox sent some specimens of this species that had been collected by Roy Robinson near the Meade River at Point Barrow, Alaska, on August 15, 1952. Lawrence C. Bliss collected for the writer about 50 specimens of this species from depressed polygons on the coastal plain of Alaska at lat. 70° 25″N., long. 150° 40″W., on August 6, 1953. This locality is about 18 miles south of the Arctic Ocean and about one-quarter of a mile east of the Colville River. The polygons, formed by ice action, were about 2–4 feet deep, for the most part, and had an average diameter of 10–20 feet. Specimens were collected from six of them, and many of the animals observed were in copulation at the time. The polygons do not dry out as do temporary ponds in the temperate belt, but they do freeze to the bottom. Thus, the eggs of fairy shrimps are just as effectively removed from free water, a condition which usually seems to be necessary before they will hatch in any quantity. The name of this species was misspelled as *P. hanseni* by Daday, in 1910, and copied by most North American writers ever since. The correct spelling is *P. hazeni*.

Recently, specimens of another arctic species seldom collected have come to hand. Ten specimens of *Artemiopsis stefanssoni* Johansen were



FIGS. 1–6.—*Branchinecta mackini*, n.sp.: 1, Head of male; 2, swimming appendage of male; 3, cercopods of male; 4, penis; 5, head of female; 6, egg sac.

collected from a lake 3 miles north of Mound Bay Weather Station, Prince Patrick Island, in Northwest Territory, Canada.

Thamnocephalus platyurus Packard is now known from Utah, Nebraska, and Missouri. Specimens of the former two were sent from the U. S. National Museum. Two males and four females were collected from an impoundment of fresh-water at Monument Valley, Utah, by Marvin Walter on August 10, 1952. A single female specimen was collected by Dr. H. W. Manter from the western part of Nebraska. Date and locality were not recorded. Also, from the National Museum were sent specimens which are the second State record from Nevada, the first having been published in my previous paper. Two females were collected from near Dry Lake, 6 miles west of Boulder City, on October 29, 1952, by Mrs. V. B. Vehling. One specimen measured 28 mm. in total length. Dr. Ira La Rivers sent another lot of two females collected from the same region. One of his students, E. A. Carl, found them at "Dry Lake, 4 miles south of the railroad pass between Las Vegas and Boulder City, Clark County, on September 17, 1953." The first records from Missouri were sent by Dr. Peter W. Frank, of the University of Missouri. He and one of his students, Robert W. Kelly, collected *T. platyurus* in July 1954 and from June to September 1955. They were collected from more than 15 temporary pools on the north bank of the Missouri River flood plain between Jefferson City and Booneville, and they were much more abundant during the latter year.

Eubranchipus vernalis (Verrill) has been found in Delaware, Maryland, and Virginia for the first time. R. S. Bray collected this species in Newcastle County, Del., on December 29, 1940. He also found it in a barnyard at Yellow Springs, Md., on December 14, 1940, and in Loudoun County, Va., on March 2, 1942. The occurrence of this species from Kentucky, inadvertently omitted from my earlier report, seems to rest solely upon an early record (1874) from near Covington. Additional records have recently come to the attention of the writer. Dr. Gerald A. Cole, of the University of Kentucky, collected *E. vernalis* between 1950 and 1954 from seven temporary pools and one permanent pond, which has dry margins annually, in various parts of Jefferson County. For the most part these pools were formed by flood waters of the Ohio River. In 1955 the water level was so high that these pools were washed over by the flood waters of the river, which carried away any pond fauna that had developed by early spring.

Eubranchipus neglectus Garman was described from Kentucky. The U. S. National Museum has eight specimens of *E. neglectus* collected from a clay pit near New Philadelphia, Ohio, by Dr. Victor Sterki. No date was recorded. Identification was made by Dr. E. P. Creaser and Dr. Folke Linder. This record extends the known range to eastern Ohio.

Eubranchipus serratus Forbes is now reported from Virginia and Maryland for the first time, and the second record from Indiana and Montana are listed. R. S. Bray collected this species on December 15, 1940, at Daday's Pond in Loudoun County, Va. A second lot was collected on April 5, 1941, from a cornfield pond near Seneca, Md. Dr. R. B. Brunson obtained the second record of this species from Montana with specimens he collected from Union Creek on April 17, 1951, and from a pond near Kicking Horse Reservoir on April 23, 1951. Identifications were made by Dr. N. T. Mattox, who sent the records to the writer. The first record from Indiana was recently published (Dexter, 1953). The second one from this State was made by Dr. Clarence Goodnight, who found this species in a gravel pit near West Lafayette in April 1953. Although most of the specimens received from him were mature, they were smaller than usual in size, averaging only 12 mm in total length. Dr. Mattox noted that the specimens from Montana were also smaller than average. It has been the experience of the writer to find that fairy shrimps vary greatly in size, not only in different geographic localities and during different years, but also in the same general locality at the same time.

Eubranchipus holmani (Ryder) has been collected in Maryland for the first time by R. S. Bray. Two males and two females were found at Martinsburg on April 16, 1940. A single male was taken from a barnyard pond at Yellow Springs on December 14, the same year, and two males and four females were collected in the Sunday Swamps at Bear Island on March 22, 28, and May 14, 1941. In my previous paper I overlooked an old published record of this species from Pennsylvania and from Minnesota. These States should now be added to the list.

Artemia salina (Linnaeus) is usually found in saline lakes and evaporating basins. Only rarely

is it found in temporary pools. However, Ernest J. Roscoe collected specimens from a temporary pool northwest of Granite Mountain in Tooele County, Utah, on October 6, 1953. Recently this species was reported from Saskatchewan for the first time (Moore, J. E. 1952). It was found in abundance in Little Manitou, a saline lake.

Branchinecta shantzi Mackin is now reported for the first time from Nevada. Dr. Ira La Rivers collected 10 females and 8 males from railroad playa northwest of White Mountain in Washoe County on May 16, 1940.

Branchinecta coloradensis Packard, formerly known quite generally as *B. lindahli* until the genus was revised by Mackin (1952), is now known from Washington, California, and Utah. Dr. R. M. Bond obtained a large number of specimens, not quite mature, from a pool on the east side of the Columbia River, 2½ miles northeast of Vantage Bridge in Washington, on March 26, 1937. Dr. Ira La Rivers collected *B. coloradensis* on July 23, 1953, at upper Convict Creek basin in Mono Co., Calif., some 35 miles north of Bishop. Abundant specimens were found in several temporary meadow pools, formed from melting snow. The water temperature at the time of collecting, however, was 24°C. These pools are on the eastern slope drainage near the crest of the southern Sierras at an elevation of 10,300 feet. By August 13 all but the largest one had dried out. Records of this species collected by Dr. La Rivers and T. J. Trelease from Marble Butte in Nevada published in my previous paper did not include the dates. The dates of collecting were March 31 and April 23, 1949. The first Utah collection of *B. colcradensis* was made by Nyvin Marchette on April 19, 1954, from a temporary pond in Government Creek Valley, Tooele County. These were sent to me through the courtesy of Ernest J. Roscoe. Dr. Elizabeth McClintock obtained the second record of this species from Arizona by collecting specimens from temporary pools in red sandstone rocks in Toroweap Valley of Mohave County about 1 mile from the rim of the Grand Canyon, on May 6, 1952.

Two errors that have appeared in recent literature concerning *Branchinecta lindahli* should be corrected. First, W. G. Moore (1950) published a record of *B. coloradensis* from Texas that should have been designated as *B. lindahli* through an error on the part of the writer. Specimens sent by Dr. Moore were identified before the revision of the genus by Mackin (1952), and a misinterpretation led to an incorrect diagnosis. Secondly, in Mackin's revision (ibid.) of Branchinecta, the species *B. lindahli* Daday, 1910, is cited as a synonym of *B. lindahli* Packard 1883, whereas it should be listed in the "non" group. It is unfortunate that so much confusion has developed in the published literature on this genus in North America to continually plague students of the group since the genus was first found here.

Streptocephalus texanus Packard is now reported from Montana and Missouri. It was collected for the first time in Montana by H. E. Nelson, who found specimens at Glasgow in May 1952. This represents the most northerly locality from which the species has been recorded to date. This record, and the one of *S. seali* from Montana mentioned below, were brought to my attention by Dr. Mattox, who had received specimens for study from Dr. R. B. Brunson. Dr. Peter Frank and his student Robert Kelly have collected *S. texanus* from temporary pools along the north bank of the Missouri River near Booneville, Mo., in recent years. Specimens without field data were examined by the writer.

Streptocephalus seali Ryder is now recorded from North Carolina, Maryland, Missouri, Montana, and California for the first time. The U. S. National Museum contains specimens of *S. seali* collected by S. F. Hildebrand on June 3, 1926, from Thomas Pond No. 3 at Beaufort, N. C. R. S. Bray collected specimens from Bear Island, Md., on November 16, 21, and 28, and December 5, 1937, and again on August 6 and September 2, 1938. Dr. James Kezer, formerly at the University of Missouri, sent numerous mature specimens, 28–30 mm in length, which he collected in the fall of 1952 from a mud hole not far from the Missouri River near Booneville, Mo. They were still living in the pool on November 10. The water was clouded with mud and as a consequence the fairy shrimps were colorless. This relationship has been observed by the writer for several species of Anostraca. Late in October 1953 and in the latter part of March 1954, Dr. Kezer again found *S. seali* in the same mud hole. Dr. Peter Frank and Robert Kelly subsequently found the same species in many ponds of various types in the area. Dr. N. T. Mattox sent a record of *S. seali* collected from Glasgow, Mont., in May 1952 by H. E. Nelson. In the collections of the U. S. National Museum

there are specimens of this species collected in September 1930 from a pond in the Sierra Nevada at an elevation of about 9,000 feet. The locality was in Tuolumne County, Calif., and the collector was R. Innis Bromley. Dr. Mattox has sent a record of *S. seali* collected by Dr. R. E. Smith from Eldorado County, Calif., on July 11, 1936. Dr. Douglas M. Whitaker has collected this species from the same county. On September 4, 1952, he found many specimens in a temporary pool filled from melted snow at an elevation of 6,600 feet in the Sierra Nevada of Eldorado County. The pond is located approximately half a mile east of Fallen Leaf Lake and about 4 miles south of the southeastern end of Lake Tahoe. Usually this pond dries out late in summer or early in fall, but heavy snows of the preceding winter caused it to persist through the season of 1952. Four male specimens ranged in size from 30 to 36 mm, with an average of 34 mm. In my previous paper I overlooked an early published record of this species from the State of New York, which should now be added to the list of known State records.

ADDITIONAL RECORDS OF COLLECTING TWO SPECIES OF ANOSTRACA TOGETHER

More records of finding two species of fairy shrimps in the same pond have come to hand. The 12 specimens of *Eubranchipus vernalis* and the single one of *E. holmani* collected at Yellow Springs, Md., as mentioned earlier in this paper, were found together. The specimens of *Streptocephalus seali* and *S. texanus* mentioned earlier from Glasgow, Mont., were together in the same vial and had a common label so that presumably they were found together. Likewise, specimens of these same two species reported above from Booneville, Mo., have been collected together. The writer collected *Eubranchipus vernalis* and *Chirocephalopsis bundyi* together in another locality of northeastern Ohio. They were found in a button-bush swamp pond near Mogadore in Portage County on April 27, 1952. The following year this pond did not fill with water, but in 1954 enough water accumulated to hatch out a few of each species. In the spring of 1955 there was an abundance of both species living together. The ratio, as determined by a count of 251 males, was 1 *E. vernalis*:1.5 *C. bundyi*. In a collection of fairy shrimps made by Walter Hintz near Pokagon State Park some 5 miles from Angola, Ind., there were 23 males of *E. vernalis* and 8 males of *C. bundyi*. They were found together on April 16, 1954, in a pasture pond. On March 17, 1952, a single specimen of *E. serratus*, 26 mm in length, was collected by the writer with 11 specimens of *E. vernalis* in a pool on the flood plain of the Salt Fork River near Homer, Ill. *E. vernalis* is the only species previously collected in this pond and in two others nearby, but all other ponds sampled in this section of Illinois have contained *E. serratus* as the common species (Dexter, 1953). Lawrence C. Bliss collected *Branchinecta shantzi* and *Chirocephalopsis bundyi* together from a small morainal pond at an elevation of 9,900 feet in the Medicine Bow Mountains of Wyoming on June 23, 1955. These species were found separately in three other ponds in this area (two with the former and one with the latter). Dr. Peter Frank and his associates have collected *S. seali* and *Thamnocephalus platyurus* together in pools near Booneville, Mo. Dr. A. S. Lockley at the Los Angeles State College collected *T. platyurus* along with specimens that proved to be the new species *Branchinecta mackini* described in this paper. They were taken from Bicycle Dry Lake, near Barstow, Calif., in November 1955.

FAIRY-SHRIMP POPULATIONS STUDIED IN ILLINOIS, 1951–1955

After my previous report on observations of fairy-shrimp populations in east-central Illinois was published, this field study was limited to six of the ponds which had been studied earlier. One new station was added in 1953. Table 1 gives a résumé of observations made in the third week of March for the years 1951–55, inclusive. No visits were made in 1954, but residents in the area reported a very dry spring during which time the temporary pools contained no water. It can be assumed that fairy shrimps did not hatch in these stations during 1954 for lack of water. The following year conditions for fairy shrimps were only slightly better.

In addition to the five temporary pools and one permanent pond (no. 8, near Urbana) sampled in 1951, Miss Sarah A. Joyner found three ponds 6 miles northeast of Urbana which were inhabited that spring by fairy shrimps. One was a permanent woodland pond in Trelease Woods, another was a permanent grassland pond, and the third a temporary pool, the latter two situated in nearby Trelease Grassland. The two permanent ponds have a dry margin during

the summer season, which is always found in such bodies of water which contain fairy shrimps. Samples of fairy shrimps were collected by Miss Joyner in all three during the spring of 1951. She collected mature specimens of *Eubranchipus serratus*, identified by the writer, on March 8, 1951, from the permanent grassland pond.

In 1951 the collections were made on March 21 from five selected stations chosen from those formerly studied. Specimens were obtained from under a cover of ice. Two days later another collection was made after the ponds had thawed. The populations sampled that year were small. However, during the next two years they increased in number each year for the most part. Those records showing a wide range of sizes undoubtedly represent more than one hatching brood as the result of rising water levels with each new rain. The collections of 1952 were taken from under a skim of ice which coated most of the ponds. That year, one pool on the flood plain of the Salt Fork River near Homer yielded one specimen of *E. serratus* as well as its usual population of *E. vernalis*.

In spite of the fact that pond no. 8 near Urbana was bulldozed to a depth of 11 feet during the summer of 1951, fairy shrimps hatched in abundance the following spring. Apparently many eggs were left still exposed at the surface although great quantities of eggs must have been buried deeply by the earth-moving operations. By the next year, however, game fish had been introduced into this pond, and fairy shrimps were not found there again.

The season of 1953 was a favorable one for fairy shrimps. A new pond adjacent to the one at Oakwood was sampled for the first time. In the spring of 1954 water was not known to collect in any of the temporary pools under observation because of a severe drought in the area. (The same situation was reported by Dr. James Kezer for the region of Columbia, Mo. Ralph W. Stark found a similar situation in Boone County, Ind., until March 19, when rain broke the drought. On March 28 a heavy rainstorm there filled the pools bringing out a hatch of *E. vernalis*. In Portage County, Ohio, the writer was not able to collect fairy shrimps in some of the stations under observation until the middle of April, when rain filled many of the depressions for the first time that year. Studies on fairy shrimps in Ohio will be reported in a separate paper.)

In 1955 dry conditions still prevailed in Illinois. One pool (no. 2 near Oakwood) had 4 inches of water when examined, but no metanauplii were found in the plankton sample taken. Pond 7 near Urbana, however, had sufficient water to bring out a good-sized population of *E. serratus*.

In 1951 the sex ratio of *E. serratus* determined by a sample of 204 individuals was 1 male:1.2 females. The following year a reverse ratio of 1 male:0.6 female was found in a sample of 162 individuals. Dexter and Kuehnle (1951) found males of *E. vernalis* to predominate (1:0.8) in two of the counties in Ohio sampled, while females predominated in two other counties (1:1.5). Coopey (1950) found the sex ratio of *E. oregonus* to change markedly during the season as the males died off at a much greater rate. W. G. Moore (1955), on the other hand, found a balanced ratio of approximately 1:1 throughout the season in populations of *Streptocephalus seali* he studied in Louisiana.

SUMMARY AND CONCLUSIONS

1. *Branchinecta mackini*, n.sp., is described from specimens collected in Nevada, Washington, and California.

2. The known geographic range of the following species is extended by recent collections: *Thamnocephalus platyurus*, *Eubranchipus vernalis*, *E. neglectus*, *E. serratus*, *E. holmani*, *Branchi-*

TABLE 1.—COLLECTING RECORDS OF ANOSTRACA IN EAST-CENTRAL ILLINOIS

Location of ponds	Pond No.	1951	1952	1953	1955
Near Oakwood-Field ditch	1	S, 9–30.5	C, 13–23	A, 2–20	Dry
Near Oakwood-Field ditch	2	—	—	N, 13–22	0, nearly dry
Near Homer-Flood plain pool	2	S ♂, 9–24.5	R, 26; S ♂, 22–27	N ♂, 4.5–9.5	Dry
Near Homer-Flood plain pool	3	0	0	0	Dry
Near Urbana-Pasture pool	7	S, 5–16.5	C, 9–29.5	N, 9–21	N, 8.5–12
Near Urbana-Pasture pool	8	N, 16–30	A, 17–27	0 (fish intro.)	—
Near Urbana-Pasture pool	9	S, 4.5–23	Destroyed	—	—

Relative abundance is indicated as follows: A—abundant; C—common; N—numerous; S—scarce; R—rare; ♂—*Eubranchipus vernalis*. All other records are for *E. serratus*. Beside the symbol for abundance is given the range in size expressed in millimeters on date of collection.

necta shantzi, *B. coloradensis*, *Streptocephalus texanus*, *S. seali*.

3. New localities with notes on habitats are given for *Polyartemiella hazeni*, *Artemiopsis stefanssoni*, *Artemia salina*.

4. New records are cited for finding the following species living together in the same pond: *Eubranchipus vernalis* with *E. holmani*; *Streptocephalus seali* with *S. texanus*; *E. vernalis* with *Chirocephalopsis bundyi*; *E. vernalis* with *E. serratus*; *Branchinecta shantzi* with *C. bundyi*; *S. seali* with *Thamnocephalus platyurus*; *T. platyurus* with *B. mackini*.

5. Fairy-shrimp populations studied in seven pools in east-central Illinois during March 1951–55 are reviewed. Two species were collected: *E. serratus* which was common in most cases and *E. vernalis* which was uncommon and found in a single pool. Insufficient rainfall in the spring of 1954 prevented a hatch that season, and in the following spring only one pool had enough water to support a population. The years 1952 and 1953 were favorable ones for the fairy shrimps. Sex ratio of *E. serratus* was 1 male:1.2 females in 1951 and 1 male:0.6 female in 1952.

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NOTES AND NEWS

A SONIC TECHNIQUE FOR TESTING LEATHER

A nondestructive method for testing leather, based on the transmission of sound waves, has recently been developed by the National Bureau of Standards. The chief instrument employed is a pulse propagation meter which measures and records the speed of a generated sound pulse through the leather. As a result, the specimen under test is left unharmed, in contrast to the tearing or other destructive effects of existing test procedures.

The experiments[1] carried out at the Bureau have shown that the velocity of sound transmission in leather varies substantially with changes in chemical and physical structure and, particularly, in fiber orientation. Velocity measurements, accordingly, are indicative of modifications of the fibrous order produced by strain, aging, and impregnating material. The study that supports these conclusions was sponsored by the Office of the Quartermaster General, Department of the Army, and was conducted by Joseph R. Kanagy and Myron Robinson, of the NBS staff.

In recent years the use of sonic techniques to determine certain mechanical properties of high polymers has become widespread. Such methods have employed frequencies ranging from less than 1 cps up to several megacycles. The use of a single frequency throughout a series of tests readily permits mathematical analysis of the data and determination of the physical constants characteristic of the viscoelastic behavior of the material. Besides furnishing a means for securing fundamental information, sonic methods have been successfully utilized in nondestructive testing. These applications relate mainly to the location of flaws in a variety of manufactured products.

The investigations of the NBS leather laboratory are part of a larger program of fundamental and applied research on natural and synthetic polymers—rubber, plastics, textiles, leathers, and papers. This program seeks not only to improve present basic knowledge of high polymers but also to make possible their more effective utilization in commercial products. The present study of the potentialities of sound-transmission measurements is expected to provide the basis for im-

[1] For further technical details see *Studies on leather by means of a sonic technique*, by J. R. KANAGY and M. ROBINSON, Journ. Amer. Leather Chem. Assoc. (in press).

proved methods of testing finished products like military footwear as well as the unworked hide.

The Bureau's sonic experiments were based on the relationship between sound velocity and the elasticity of the medium as given by Young's modulus. If a sound wave is propagated along a medium whose transverse dimensions are small compared to the wavelengths utilized, then the following well-known relation holds:

$$E = v^2\rho \qquad (1)$$

where v is the velocity of sound, ρ is the density of the medium, and E is Young's modulus, the latter being defined as the force per unit cross-section area required to produce unit elastic strain. However, if the material produces appreciable acoustic attenuation, as shown by a notable decrease in the amplitude of the sound wave as it travels through the medium, the single relation given above no longer suffices for an accurate determination of the modulus. An additional factor based on a viscosity coefficient must then be applied to the right-hand side of the equation.

In the current investigation, estimates of sound attenuation in leather were obtained by observing on an oscilloscope the decreasing amplitude of a particular section of a 3,000-cps wave train as the transmitter and receiver crystals of the propagation meter were separated. On the basis of these rough measurements, the attenuation for shoe-upper leather was estimated at 0.1 to 0.2 nepers per cm. For purposes of comparison, the attenuation constants were also obtained, under the same conditions of frequency and temperature, for other polymeric materials, with these results:

polyethylene	0.012 nepers per cm
nylon (undrawn filament)	0.003
neoprene GN at 6 percent strain	0.51

It may be seen that the acoustic attenuation in leather lies midway between that of materials with highly crystalline fibers and that of rubber-like materials.

In developing leather test methods, attenuation and frequency are of secondary importance since only relative velocity measurements are required to establish the deviation of a sample from its control. The data of this investigation were therefore studied in terms of the more directly measurable quantity, velocity. Now, the defining equation,

$$E = \frac{\text{stress}}{\text{strain}} = \frac{\text{load}}{\text{elongation}},$$

makes clear the direct relation holding between E and the resistance to elongation. In the light of this relation, equation (1) may be interpreted as saying that the speed of sound through a medium such as leather is greatest in the direction that offers the greatest resistance to elongation—that is, along the individual fibers.

In experiments with leather from cattlehide, the speed of propagation of sound varied with the lateral dimension of the specimen, increasing with width up to a certain maximum dependent on the wavelength of the sound. In cattlehide the fibers are oriented at random; consequently, there is no sound path directly along the specimen. That the speed of sound through a material like leather is related to fiber orientation was shown with vegetable-tanned sharkskin. In sharkskin the fibers occur naturally in a highly oriented basket-weave pattern, the two fiber axes being mutually perpendicular in the plane of the hide. Specimens were cut so that sound could be transmitted either in the direction of a fiber axis or at a 45° angle with the axes. The specimens cut at an angle of 45° with the fiber axes should have sound paths roughly comparable with those existing in cattlehide, and a similar velocity-width relation would be expected. On the other hand, specimens with one set of fibers oriented in the direction of sound propagation should show no velocity decrease when width is decreased, since there is a sound path that goes directly through the specimen. For both types of specimen, experiment conformed to expectation. The 45° cuts showed the same sort of velocity-width relation as did leather, and in parallel cuts the velocity was independent of the width within experimental error. The velocity of parallel propagation was also observed to be greater than the maximum velocity in the oblique direction.

Additional evidence that sound propagation follows fiber orientation was obtained from experiments with kangaroo tail tendons. These tendons are composed of collagen fibers highly oriented along a single direction. The speed of propagation through the tendons was approximately 2,000 meters per second, or about three times greater than the speed in cattlehide.

Another study showed that the speed of sound through leather increases with period of aging at

100°C until it reaches a maximum. Therefore, an indication of the quality of a sample of leather may be obtained by comparing the speed of sound through the sample with the maximum speed in a control specimen that has been subjected to aging.

It is thus possible, without harming the specimen, to detect changes in fiber orientation caused by strain, aging, and filling by comparing sound-velocity measurements. Moreover, there is good correlation between sonic measurements and the results of tensile and breaking elongation tests. The effects of tannage, grease, and moisture can also be demonstrated. Finally, for an inhomogeneous material such as leather, the sonic technique has the distinct advantage of providing a means of following the effects of aging, chemical treatments, and the like on a single specimen.

ARCTIC MARINE INVERTEBRATES STUDIED

Abundant and often fantastic are the animals of the shallow Arctic sea bottom. All are invertebrates—worms, sea anemones, and a host of others—many of which spend their lives buried in the bottom mud. They are described in a report recently published by the Smithsonian Institution by Prof. G. E. MacGinitie on his collections while principal investigator at the Navy's Arctic Research Laboratory at Point Barrow, Alaska.

Some of the creatures and their curious ways of life, as related in the report, follow.

A delicately peach-colored sea anemone, a bottom-dwelling animal remotely related to the coral polyps, which displayed what Professor MacGinitie calls an "amazing phenomenon." "When it was subjected to unfavorable conditions, such as overcrowding in a pan or jar of sea water," he says, "it cast out through the mouth a translucent white inner lining, with translucent, stubby tentacles. This offspring was somewhat suggestive of a pickled onion. If conditions remained adverse more offspring were cast off, each one becoming smaller than its predecessor." In other words, when in trouble the animal spits out babies—presumably an emergency measure for preservation of the species. Apparently the same thing happens in the sea. Partly grown specimens of these offspring dredged from the bottom at first were mistaken for a new species. Some quite colorful types of these animals were found—one purplish-red, one lavender, one lemon-yellow, and one with translucent, peach-colored tentacles.

Among the more abundant animals found on the shallow bottom were nemerteans, or ribbon-worms, notable for their ability to stretch the body to twice or more its normal length. Two specimens of one species that washed ashore had, as a means of self preservation, Professor MacGinitie says, "literally tied themselves in knots, curled up into balls, and then secreted bags of mucous around themselves."

Very abundant mud-dwelling animals off the Arctic coast are the echiuroids, otherwise known as "spoonworms," or "sausage-worms." They burrow very deeply in the mud and are seldom seen unless washed ashore in storms. One species was bright green in color and about 3 inches long; these worms, Professor MacGinitie found, were eaten raw by Eskimos.

Among the most abundant animals in the sea are the small, transparent *Sagitta*, or arrow-worms. Thousands were obtained in tows for plankton. One species, about half an inch long, apparently is among the kangaroos of the invertebrate world. "Two specimens," the report says, "were carrying young in a marsupium (pouch) formed by folding the posterior lateral fins together. In the laboratory some of the young about 3 millimeters long began escaping from this marsupium."

An extremely important part of the bottom fauna at Point Barrow, Professor MacGinitie found, were the bryozoans. They are colonial animals, somewhat like corals but of a higher order, which cover stones with growths that sometimes look like patches of moss, sometimes like weavings of delicate lace. Hardly a stone was found which did not have at least one "moss patch." Sometimes the entire surface would be covered. These miniature moss forests provide refuge for numerous other minute animals. Some of the lacelike colonies are quite beautiful. Some form peach-colored, some deep red, and some yellow lacework.

Marine annelid worms, or polychaetes, comprise an important group in the Point Darrow fauna. Among them was one species, of the type known as syllids—a flesh-colored worm with brownish-red eyes which emitted a bluish-white light. It lived ordinarily hidden among the bryozoan growth on stones, but its luminescence betrayed it.

Numerically the most abundant animals are amphipods, members of the sand-flea family, which form an important food source for fishes and seals. Great numbers live on the underside of ice cakes from which the bearded seal can sweep them with its whiskers. If seals can live on them, why not men? "It would seem," says Professor MacGinitie, "that they should form a source of food for military personnel forced to abandon ship or make a forced landing. *Apherusa glacialis* (the species found in such numbers on the bottoms of ice cakes) could be gathered with nets from the swarms that dart away when an ice cake is disturbed." This species is circumpolar in distribution.

E. C. Crittenden

Dr. Eugene Casson Crittenden, 75, internationally known scientist and expert on standards of physical measurement, died of cancer on Wednesday, March 28, 1956, at Garfield Hospital, Washington, D. C., after an illness of several months. He had retired as associate director of the National Bureau of Standards in December 1950 but had continued to serve the Bureau as a consultant to the director up to the time of his illness.

Dr. Crittenden is perhaps best known for his achievements in the development and adoption of electrical and photometric standards. As vice president of the International Commission on Illumination, from 1939 to 1948, and president of its U. S. National Committee from 1928 to 1935, he played a major role in the establishment of modern photometric units, standards, and methods of measurement which culminated in the international adoption of the "candela" in 1948. As the United States representative on the International Committee on Weights and Measures from 1946 to 1954, its vice chairman from 1950 to 1954, and as chief of the Bureau's Electrical Division for many years, he was a leading scientific figure in replacing the obsolescent international system of electrical units by the so-called absolute electrical units. These new units provide a basis for all electrical measurements now made in this country and throughout the world; they were given legal substance by Public Law 617 passed by the 81st Congress.

Crittenden was born at Oswayo, Pa., on December 19, 1880. He attended Cornell University and received his B.A. degree in 1905. He remained there as an instructor and graduate student until he came to the National Bureau of Standards as an assistant physicist in July 1909. He was first assigned to the Photometric Laboratory, where he subsequently made so many important contributions. He was named chief of the Bureau's Electrical Division in 1921 and continued in this position until 1946. Under his leadership, the program of the Division expanded substantially, keeping pace with the rapid developments in radio and electronics. Major organizational units of the Bureau came from nuclei assembled under his leadership. These include the former Ordnance Development Division, now the Diamond Ordnance Fuze Laboratories of the Department of the Army, and the Bureau's Central Radio Propagation Laboratories at Boulder, Colo.

In 1933 Dr. Crittenden was made assistant director of the Bureau and placed in charge of the over-all research and testing activities of the organization. In 1946 the title was changed to associate director, and he assumed the responsibilities of this office on a full-time basis and continued in this role until his retirement. He was awarded the Department of Commerce Gold Medal for Exceptional Service in 1949, the first year in which these awards were established. In 1946 he was honored with the Gold Medal of the Illuminating Engineering Society for "meritorious achievement conspicuously furthering the profession, art, or knowledge of illuminating engineering." Also in 1946 the Case Institute of Technology awarded him an honorary D.Sc. as "a devoted servant of the public, exponent of precise measurement, and international authority on the standards of science and industry."

He was extremely active in many scientific and professional organizations. He served on the Standards Council of the American Standards Association from 1925 to 1948 and as its chairman from 1945 to 1948. He was president of the Illuminating Engineering Society in 1925; president of the U. S. National Committee of the International Electrochemical Commission from 1939 to 1946; president of the Optical Society of America, 1932 to 1933; associate editor of the *Review of Scientific Instruments*, 1934 to 1936; and chairman of the Interdepartmental Screw Thread Committee in 1952. He also participated in the work of the American Society for Testing Materials, the American Institute of Electrical Engineers, the American Institute of Physics, the National Research Council, the International Organization for Standardization, and the International Committee on Legal Metrology. Locally, he was president of the Philosophical Society of Washington in 1922, of the Washington Academy of Sciences in 1940, and of the Cosmos Club in 1946.

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